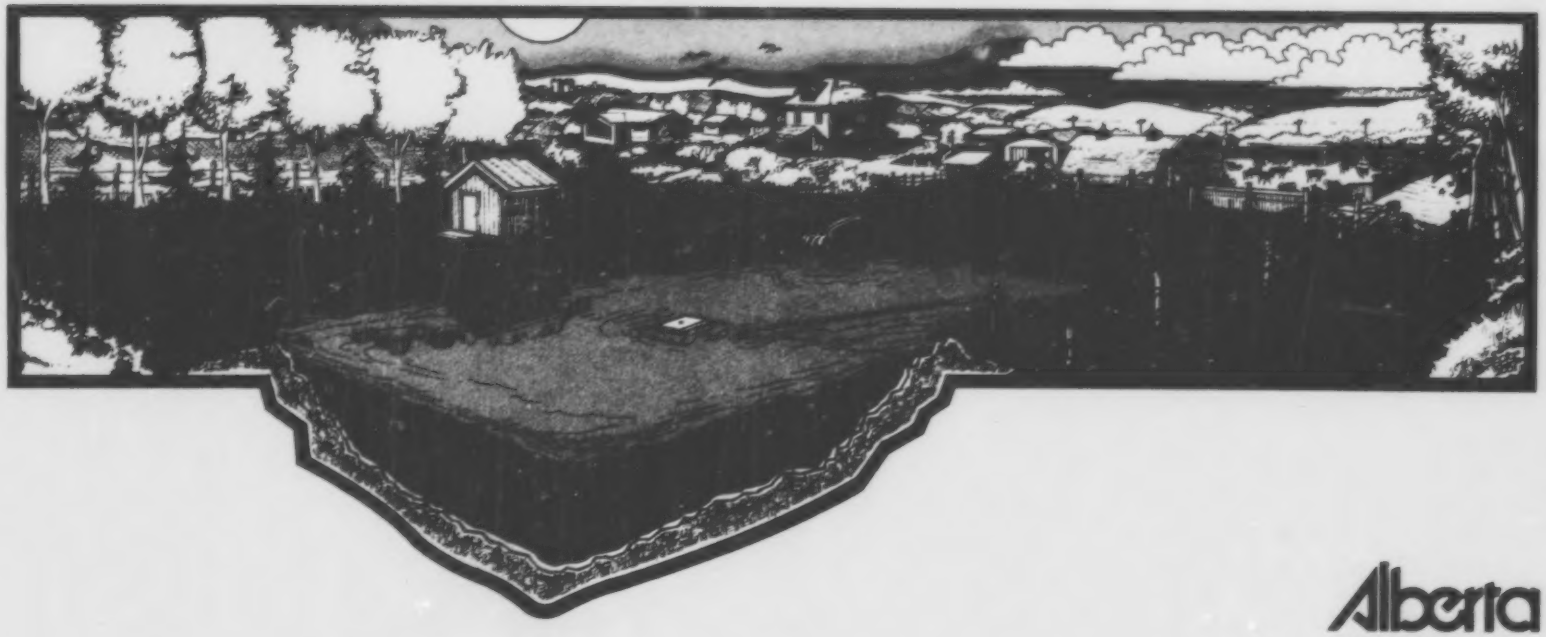
Quality FARM DUGOUTS



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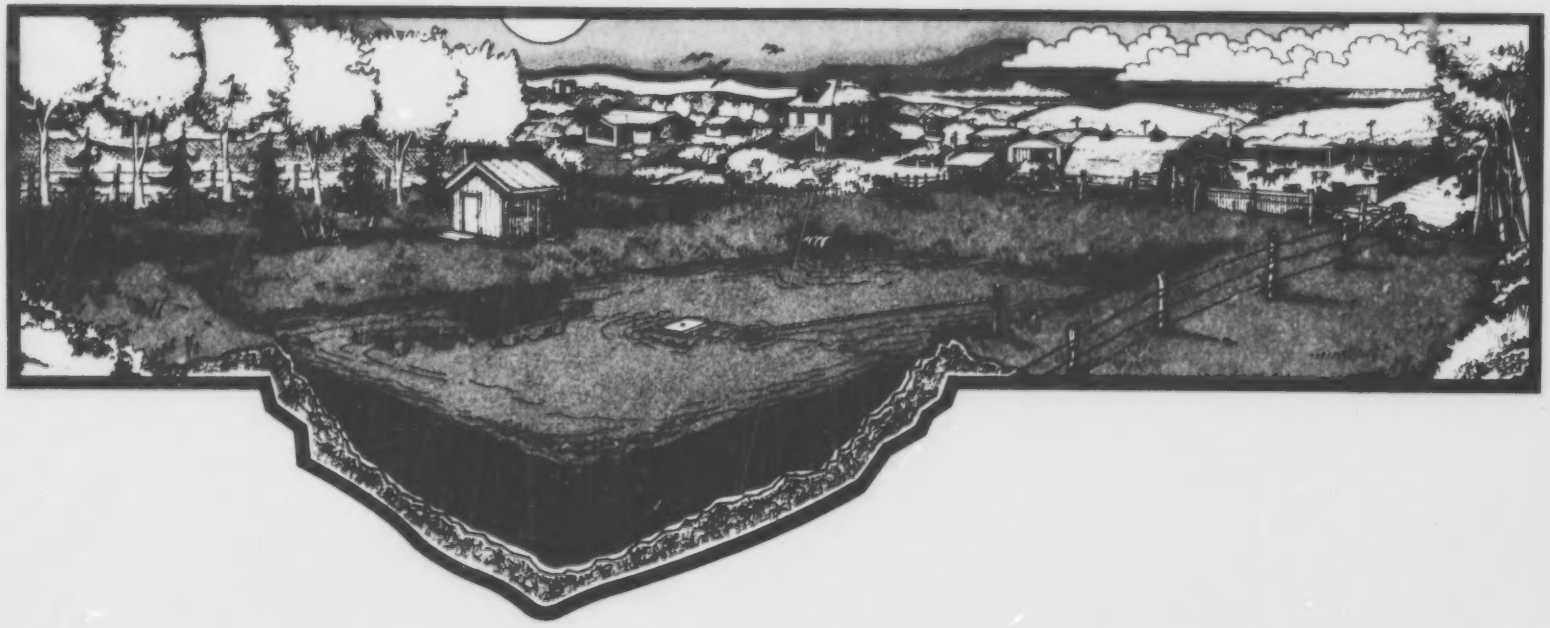
Example Worksheets

Quality FARM DUGOUTS



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Alberta AGRICULTURE, FOOD AND RURAL DEVELOPMENT

Manitoba

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Sask Water Our Water...Our Future

This publication is a production of Prairie Water News, an inter-provincial and inter-disciplinary group. Our goal is to help rural people manage dugout water supply and water quality.

Prairie Water News, which was formed in 1990, has produced a biannual newsletter about water-related issues for more than a decade. The organization is jointly sponsored by the:

- Province of Alberta, Alberta Agriculture, Food and Rural Development
- Province of Manitoba, Ministries of Agriculture, Environment, Health and Intergovernmental Affairs
- Government of Canada, Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration
- Saskatchewan Water Corporation
- Saskatchewan Research Council.

The purpose of this manual is to provide the latest research information focussed on improving both the quantity and quality of dugout water. It identifies and explains general dugout planning, design, construction, treatment, and management practices. It also recommends which practices to avoid, and attempts to dispel a few myths about dugout water management.

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All references to units of distance and volume are Imperial measurements with Mettric measurements in parentheses unless otherwise stated.

How to Use this Manual

Quality Farm Dugouts contains nine modules including a number of worksheets that complement the text and add a very practical element to the manual's use. A pocket in the front cover stores example worksheets. A pocket in the back cover stores blank worksheets and can be used to store other important documents for your dugout, such as completed estimates, record forms, and personal contacts. Although certain topics will be of more interest and value than others, we recommend that you start with Module 1 and work through the manual systematically.

Features of the Manual

Sidebars

Sidebars in the narrow columns on each page contain specialized and important comments, considerations, and reminders.

Worksheets and Maintenance Schedules

One copy of blank worksheets and maintenance schedules are included in the pocket at the back of the manual. These forms enable you to calculate and collect important information to use in planning, designing, constructing, and operating a dugout, water system. Examples of the use of each of the worksheets and schedules are included within the text and in the front pocket.

Bolded Terms

Bolded terms throughout the text are defined in the Glossary on page 105 of the manual.

Prompts

Prompts are symbols that direct you to carry out or avoid certain actions or practices.

Recommended practice or action.

Not recommended practice or action.

Remember!

Key concept, practice, or issue.

Dangerous practice, action, or issue!

Practice, action, or issue that requires caution!

Worksheet, exercise, or activity.

History

Farm dugouts on the Canadian Prairies have been used as small, water storage reservoirs for many years. In areas where groundwater is either unavailable or of very poor quality, impounding surface runoff is often the only means of ensuring a continuous water supply. For the most part, dugouts capture the temporary surplus of surface water that occurs during snowmelt in the spring. Water may also be collected as runoff from summer rains, but it is typically of very low quality. In order to guarantee reliability of supply, storage capacity must be sufficient to compensate for years of insufficient runoff, summer losses due to evaporation, and winter losses due to ice formation.

During the drought of the 1930s, PFRA helped establish design standards for dugouts to make them a more reliable source of water. They also began offering financial incentives to producers who constructed dugouts according to prescribed design standards. Since the 1930s, PFRA and other government agencies have continued to improve the basic design of the farm dugout. More than 250,000 dugouts have been constructed on the Prairies over the last 100 years.

Figure 1 Horse-Drawn Excavation

Today, many farm operations have several choices for obtaining water supplies. Some now even have access to pressurized and treated water through rural water pipelines. Despite these advances, dugouts continue to be an important part of many farm water systems.

Dugouts are an important water source on the Canadian Prairies for a wide range of uses including:

- irrigation
- greenhouse production
- pesticide spray mixing
- livestock watering
- aquaculture
- household water supplies
- human drinking water
- fire fighting.

Different dugout uses demand different levels of water quantity and quality, and in large part, determine the size, shape, location, and the type of management required.

Over the years, several agencies in all three Prairie Provinces have provided information and management advice to owners of dugouts. This information has been periodically updated as the result of fifty years of ongoing research. The provision of current dugout knowledge and management practices to dugout users helps to ensure that water is not a limiting factor in economic success or quality of rural life.

Understanding Prairie Dugouts

It is much easier to design, operate, and maintain high quality dugouts if the natural processes that control them are understood. This module explains some of these processes. Climate and landscape determine how much runoff will be captured by a dugout. Once the runoff is stored, the dugout provides an environment for a wide variety of plants, animals, and micro-organisms that can have a huge impact on water quality.

The Prairie Climate

Climate has an over-riding effect on water supplies. Three broad climate zones as shown in Figure 2 Climate Zones characterize the Prairie region:

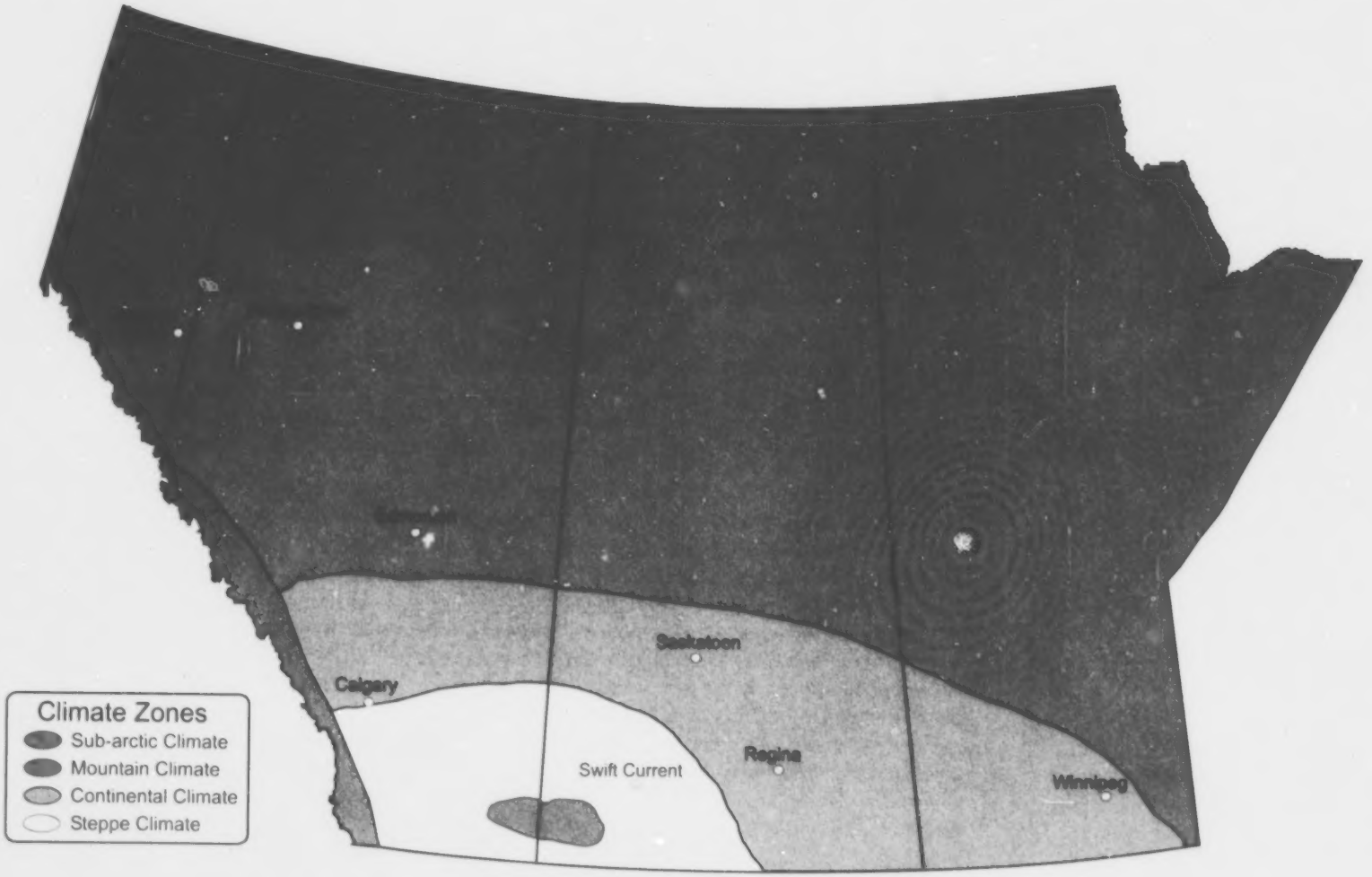
- steppe
- continental
- sub-arctic.

The steppe climate is dry year-round, with cold winters and warm summers. The continental climate is wetter, with cold winters and cool summers. The sub-arctic climate is characteristic of the boreal forest. Winters are long and cold. Summers are short and cool. The majority of the Prairie grain belt is in the continental region. Southwestern Saskatchewan and southern Alberta, with the exception of the Cypress uplands, are within the steppe region. Very little agricultural land is contained in the sub-arctic region.

With the exception of the Alberta foothills, average annual precipitation across the Prairies increases from 300 mm in the southwest to 500 mm in the northeast. Most of this precipitation occurs as late spring and summer rains. Often storm events produce floods. Winter precipitation occurs as snowfall, which usually remains all winter, melts rapidly in early spring, and creates a runoff event.

Mean annual temperature generally decreases from southwest to northeast. Southern Alberta and southwestern Saskatchewan often experience warm winter winds, called Chinooks, which produce melting and evaporation of snow during winter months. The entire Prairie region experiences an annual water deficit whereby evapo-transpiration exceeds precipitation. Because of low precipitation and Chinooks, deficits are severe in the southwest. Large fluctuations in temperature and precipitation from year to year may produce periods of drought or extreme wet conditions.

Figure 2 Climate Zones



The Prairie Dugout

"Quality Farm Dugouts" focuses on the typical family farm dugout filled from runoff.

Dugouts are earthen excavations designed to collect runoff and store it for use during drier times. Typically, dugout capacity ranges from a few hundred thousand to several million imperial gallons. **Dugouts are water sources of necessity, not of choice** because of the uncertainty of filling caused by annual variations in precipitation, and the problem of maintaining water quality. More reliable, superior quality, water can usually be provided by flowing surface water and many groundwater formations. However, for some Prairie families and agri-food operations, dugouts are the only practical water source and are relied upon for all uses. For others, dugouts may provide water for specific purposes only, such as watering livestock. Although this publication provides information about the "typical" family farm dugout, the material may also be useful to managers of very large dugouts used for irrigation or watering animals in large livestock operations.

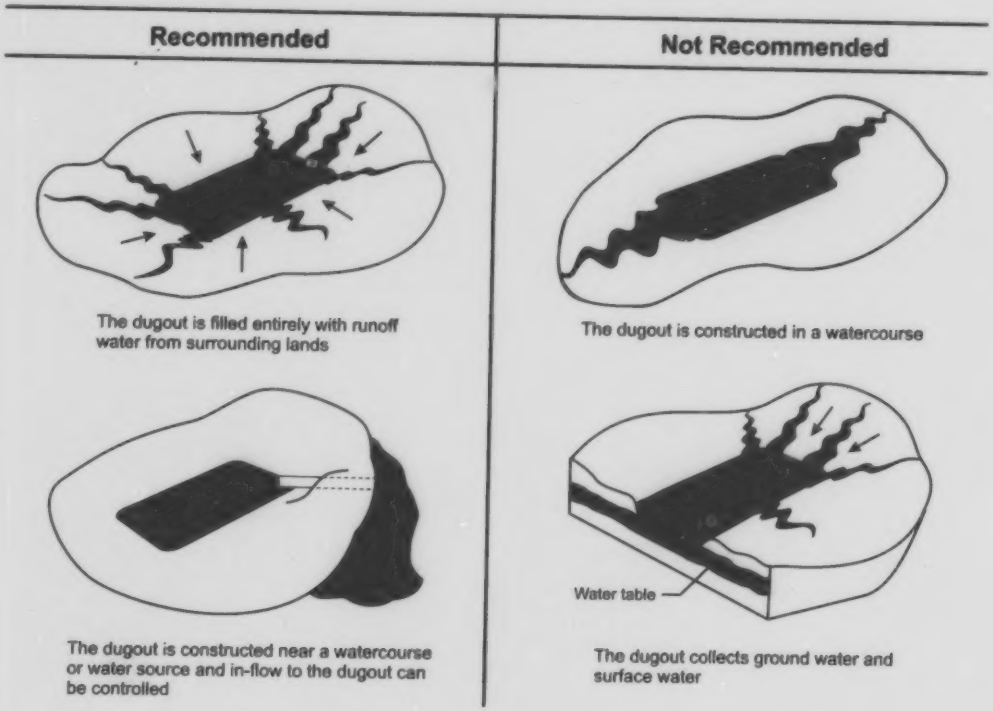
There are four major types of dugouts as illustrated in Figure 3 Dugout Types. The most common type is filled completely by runoff from surrounding fields. The second most common type is located adjacent to a flowing watercourse and is filled by either pumping or diverting water from the watercourse. For the purposes of this publication, a watercourse is defined as a creek, ditch, or other permanent or intermittent stream that has a well-defined channel with a streambed and banks.

Two other types of dugouts exist. One is an excavation made directly in a watercourse so that the stream fills the dugout and the overflow continues down the watercourse. This type of construction requires provincial approval and is **not** generally permitted because of downstream interests. With this type of construction an accumulation of nutrients and organic matter can result in poor water quality as inflow cannot be controlled. The remaining type of dugout is one in contact with shallow groundwater. This is also **not** recommended because it mixes surface water and groundwater. Surface water is highly susceptible to microbial contamination and groundwater is typically highly mineralized. Most often, this mixture produces water that is of lower quality and more costly to treat than either surface or groundwater alone. Dugout owners often mistakenly assume that water entering a newly excavated dugout from a shallow aquifer provides insurance against drought. Although water levels may rise in times of high groundwater recharge, in times of falling groundwater levels, valuable runoff that has collected in the dugout may actually drain into the aquifer. In addition to emptying the dugout, this may introduce surface contaminants to the aquifer.

If you want to collect surface water, dig a dugout. If you want to use groundwater, dig a well.

For dugouts located on uneven ground, berms can be constructed on the lower sides of the dugout using the excavated earth to enable more water to be stored. To do this, strip the topsoil down to the subsoil where the berm is to be located, and then build up the bermed area with compacted subsoil to a level two feet higher than water level. This will prevent seepage loss under the berm and overtopping of the berm from wave action.

Figure 3 Dugout Types



Dugout Water Quality

As previously noted, wells are generally preferred to dugouts because water quality in most dugouts is poor. Runoff water often brings dissolved and suspended materials that are detrimental to water quality, including:

- disease-causing organisms
- plant nutrients/dissolved fertilizers

- pesticides
- decomposed plant and algae material
- suspended sediment
- fuels, solvents, and paints
- soil minerals.

A single liter of motor oil can make two million liters of water unfit for human drinking water.

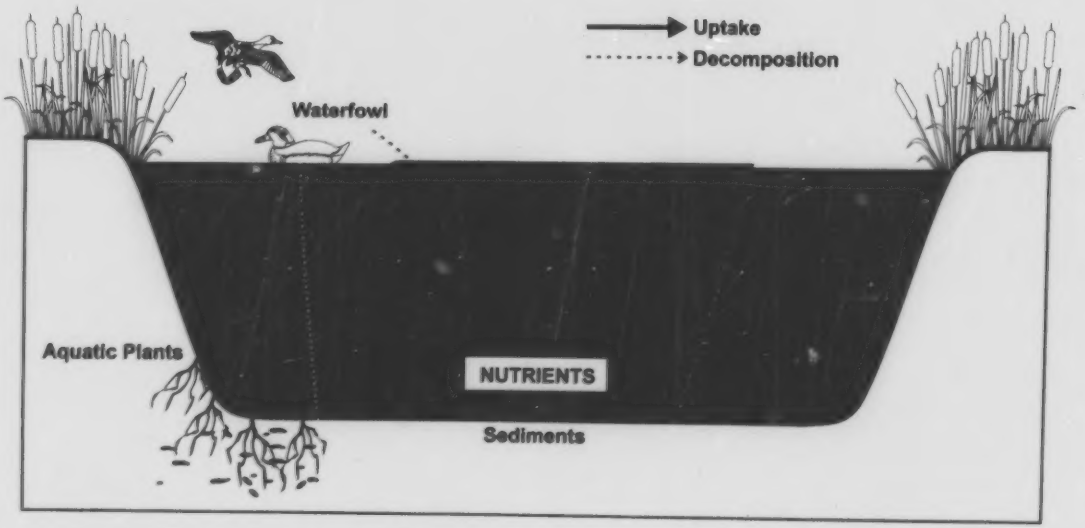
The net result of contaminant-loaded runoff is poor quality, dugout water. However, dugout water quality can be managed, improved, and treated to meet most farm needs. Attempts to manage or enhance dugout water quality must recognize and work with the natural biological and chemical processes occurring in the dugout. Good dugout management starts with the dugout watershed and extends right through to the final use.

Biology of a Dugout

Many people see a dugout as a stagnant, lifeless body of water. Nothing could be further from the truth. As a newly constructed dugout fills for the first time, it is quickly invaded by a variety of organisms, including plants, microbes, insects, and animals, and develops its own unique ecosystem. The fertile soils in which most dugouts are located contribute nutrients for plant growth. The rooted plants and algae represent an important food source for tiny animals called zooplankton. Through the food chain, the zooplankton become a source of food for insects that ultimately become a source of food for amphibians and fish. In fact, a dugout is a living ecosystem driven by natural cycles and processes.

The biology of a dugout is similar to the cycle within any other small body of water. Each summer, warm temperatures and long sunny days produce an explosion of plant and animal growth. In daylight, plants consume nutrients and pump oxygen into the water; at night time oxygen production stops and respiration consumes dissolved oxygen which can result in low dissolved oxygen levels. When they die, microorganisms decompose their tissues. This decomposition process consumes oxygen. On hot, still days biological activity is high and there is little oxygen added by wind-driven mixing of the water. In winter when the surface is sealed by ice, oxygen levels can also become very low. When this occurs, anaerobic organisms that do not use oxygen take over the decomposition process. Anaerobic activity releases many unwanted compounds into water. These include forms of iron and manganese that produce coloured water and unpleasant smelling swamp gases such as methane and hydrogen sulfide. As these microorganisms die, their decomposition also adds nutrients to the water body that become available to plants to begin the cycle again.

Figure 4 Simplified Nutrient Cycle



Many forms of plant life thrive in dugouts as shown in Figure 4 Simplified Nutrient Cycle. Some species are rooted in the dugout but are totally submerged. Others inhabit the margins where they are rooted in the sediments but hold their vegetation above the water. Cattails and reeds are examples of this type of plant. Although only one of the many forms of plant life in a dugout, algae get a lot of attention. This is primarily due to the problems they cause in a water supply. Algae can be present in dugouts but go unnoticed most of the time. When conditions are favourable, however, they can reproduce very rapidly and cause a "bloom". Algae blooms cause a variety of problems:

- toxins in the water
- water turbidity
- tastes and odours
- clogging of filters
- ineffective disinfection treatment
- formation of toxic chlorination by-products
- fluctuating oxygen levels between day and night resulting in fish kills.

The formation of toxins by **cyanobacteria** is of the greatest concern. Some are capable of producing toxins that can damage the liver, nerves, lungs, and hearts of livestock. Cyanobacteria float near the water surface and wind action blows them to the side of the dugout. When livestock water directly at the edge of a dugout, they may be exposed to high concentrations of cyanobacteria in the water. Cases of livestock deaths due to cyanobacteria have occurred in all the Prairie Provinces.

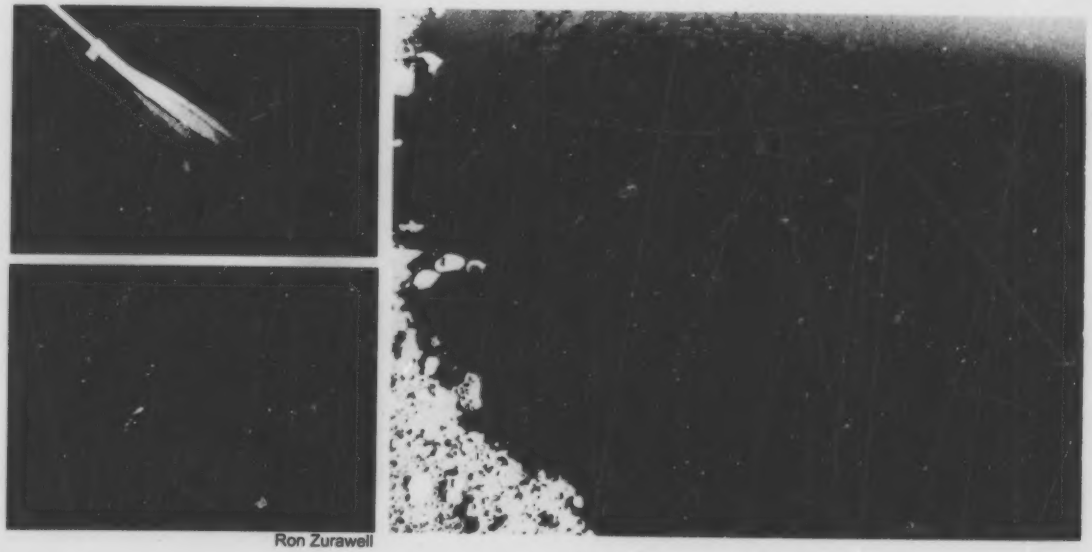
Growth of cyanobacteria is greatest when the water is warm and concentrations of nutrients, especially phosphorus, are high. It is not easy to distinguish between cyanobacteria and harmless green algae as shown in Figures 5–8. Positive identification requires training and use of a microscope. When an algae bloom occurs in water used for livestock, it is best to exercise extreme caution. Little corrective action is possible once a cyanobacteria bloom has occurred. The most effective strategy for reducing the risk is to manage a dugout so the conditions that induce large populations do not develop. Much of this manual is devoted to this topic.

Figures 5 Duckweed
Duckweed is a readily identified oval shaped plant that floats on the water surface and forms a mat that can cover the entire dugout.

Ron Zurawell

Ron Zurawell

Figure 6 Green (Filamentous) Algae
There are many types of green algae. Shown here is a filamentous type which is characterized by long threads or filaments of cells attached together and found floating as a mat on the surface. It is commonly called pond scum.



Ron Zurawell

Figure 7 Cyanobacteria
There are many types of cyanobacteria. They are microscopic in size but become visible when large populations develop forming what is termed a "bloom". Some types are extremely toxic to humans and animals.

Ron Zurawell

Figure 8 Cyanobacteria
One type of cyanobacteria is highly visible due to its "grass clipping" appearance with pieces measuring from 1/2 to 3/4 inch in length.

***Cyanobacteria** is often incorrectly referred to as blue-green algae. It is bacteria, not algae.*

A much-maligned, but harmless plant called duckweed is sometimes confused with algae. It can be readily identified upon close inspection. Duckweed is an oval shaped plant that floats on the water surface as shown in Figure 5 Duckweed. It can cover an entire water body with a green mat composed of millions of small plants. Duckweed can be beneficial in a dugout by preventing light penetration of the water and thereby shading out algae. It also takes up nitrogen and phosphorus from the water. Long-lasting benefit from duckweed is only realized, however, if plants are removed before they die and the nutrients are released back into the water. To be successful, the duckweed must be removed as often as once a month.

The Life Span of a Dugout

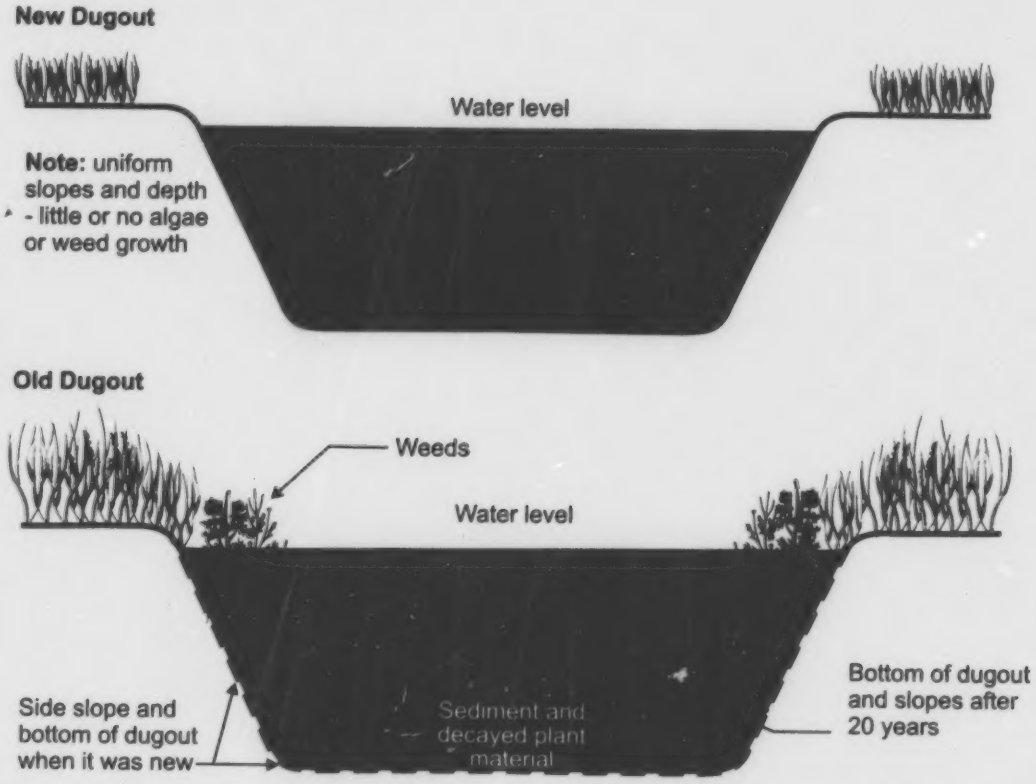
Like all man-made things, a farm dugout does not last forever as shown in Figure 9 New vs Old Dugout Cross-sections. All bodies of water, including farm dugouts, undergo a natural aging process. As the years go by, the dugout accumulates sediment from wind and water erosion. In some circumstances, an average sized dugout can collect more than 15 inches of sediment each year. This can total 50 tons or more. As the excavation fills with sediment, the holding capacity becomes greatly reduced. Some of the rehabilitation work on dugouts has shown that from 1 to 10% of water volume can be lost in a single year. Sediment also contributes nutrients that rapidly accelerate the natural aging process by increasing plant growth and lowering water quality.

Ten per cent of dugout capacity can be lost in a single year due to sediment inflow from adjacent land.

As a dugout fills with sediment, water quality deteriorates. In addition to collecting water and sediment, dugouts are very efficient at trapping the nutrients deposited from runoff to the dugout. Year after year, the accumulation of these nutrients from runoff events, plus their continual re-cycling within a dugout cause a steady increase in plant and algae growth. This leads to an ongoing deterioration in dugout water quality. A shallow dugout also warms more quickly in the summer and cools more rapidly in the winter. Warm water encourages algae growth in summer. The winter ice layer leaves even less water available and concentrates salts and nutrients in a smaller volume of water.

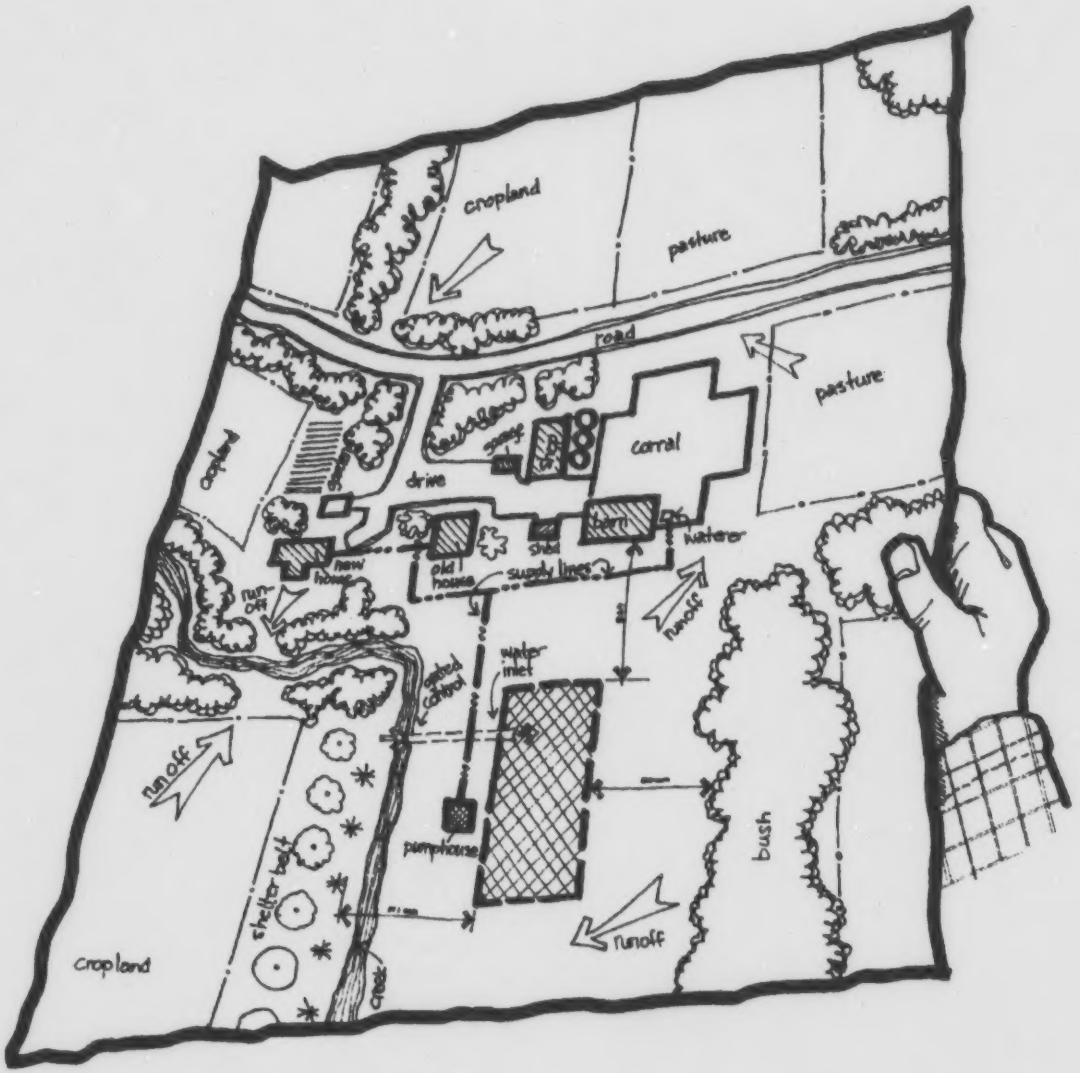
The actual life span of a dugout depends on the quality of water that is required for different uses. Drinking water must have low biological activity. Irrigation water must have low levels of soluble salts. The length of time that a dugout can sustain the required quality is dependent on land-use practices in the watershed and the actual management of the dugout. As dugouts age, lower water quality can be expected.

Figure 9 New vs. Old Dugout Cross-sections



In general, a farm dugout provides good water quality for about the first five years. Over the next ten years, storage capacity and water quality deteriorate. After 20 years, storage capacity and water quality have usually been reduced to the point where the dugout no longer meets the needs of the landowner. Regardless of its uses, the life span of a dugout can be extended significantly through effective management.

Planning


cropland
pasture
road
pasture
corral
drive
cropland
barn
shed
waterer
new house
old house
supply lines
run-off
runoff
water inlet
gated control
runoff
pumphouse
bush
shelter belt
runoff
cropland
creek

Planning Farm Water Supplies

Although a well-planned and designed water system may cost more initially, it will ultimately save money. Costly changes to correct future problems will be avoided.

The initial planning steps include:

- Determination of Water Requirements
  The first step in planning is to determine the amount of water required. Estimating future needs should take into account any anticipated changes such as an expansion or diversification of farm activities.
- Inventory of Water Sources
  The next step is to take an inventory of all water sources. Many farms use more than one water supply. Account for production rates, storage volumes, and any previous problems with water quantity or quality for each source. If the dugout is to be the only source of water, uncertainty of runoff volume should be factored into the sizing calculation. Because of frequent drought on the Prairies, it is recommended that all dugouts be constructed to hold at least a two-year water supply. In situations where the dugout is not critical to operations or alternate supplies are readily available, a smaller dugout may be chosen. Calculations in this manual, however, focus on the two-year supply.
- Land Use Planning to Protect Water Supply
  Activities within a watershed have a large impact on water quality and quantity. Evaluating and adapting farm practice where it affects runoff can do much to increase dugout utility.

Regulatory and Funding Issues

Before constructing a new dugout, it is important to be aware of legal restrictions that may apply. Ownership of surface and groundwater is vested in the provinces. Dugouts for household and livestock consumption do not usually require provincial approval. However, approval is required for the following uses:

- aquaculture
- commercial uses

- municipal uses
- tank-loading
- irrigation.

In most jurisdictions, municipal and provincial, there are also requirements for minimum setback distances from public roadways. Stocking of dugouts with fish is controlled to minimize the risks of discharges that could introduce disease and non-native species of fish into natural waterways.

Before constructing a dugout, consult appropriate authorities to ensure compliance with existing regulations. Obtaining approvals well in advance to avoid delays in construction.

The federal government, through the PFRA, and the provincial governments offer technical assistance for the construction or improvement of dugout water supplies. Financial assistance may be available for some projects. Regulations and funding vary significantly between provinces. Provincial regulation summaries are provided in Appendix 1 on page 101.

Watershed Runoff Potential and Water Quality

Both the quantity and quality of water are affected by the characteristics of the drainage area and the activities that take place within it. The most important characteristic in determining potential runoff into a dugout is the size of the drainage area or watershed. In addition, soil type, land use, topography, and vegetative cover all influence the total quantity of water that will flow into a dugout.

Watershed Runoff Potential and Dugout Sizing

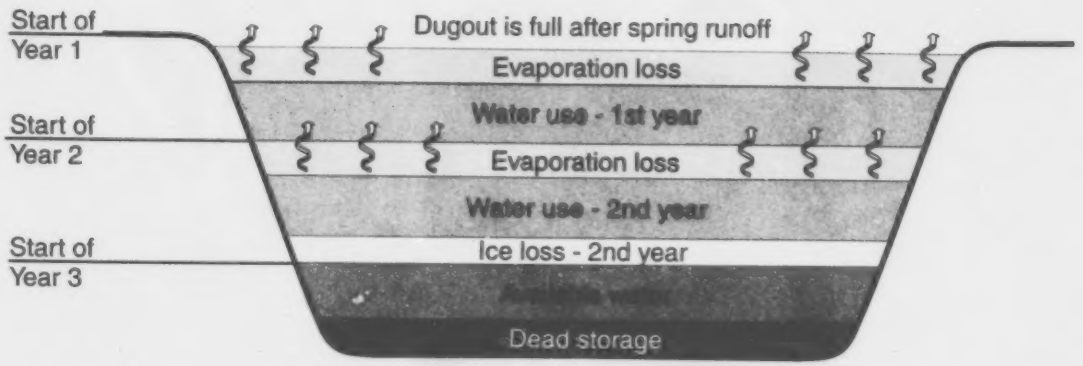
This section discusses factors that should be considered when selecting a site for your dugout. It is essential that a dugout be located to capture the quantity of water required. There are many considerations when choosing a site. Inevitably, some trade-off between conflicting factors will be required. However, it is worth the time and trouble to find the best location for a dugout that will be in use for many years.

Dugout Sizing

Dugouts fill with runoff from the surrounding land. The most important factors to consider in sizing are the potential amount of runoff that will be captured, evaporation loss, and the shape and dimensions of the dugout.

Figure 10 Dugout Size vs Available Water illustrates the necessity of sizing dugouts properly so they provide a dependable source of water. In this example, the dugout has received no runoff water in two years. The cross-sectional view shows how the supply of available water is reduced by farm use, lack of runoff, evaporation, and ice formation in winter. In addition to uses and losses, the water at the bottom of the dugout will be of such poor quality that it is rated as dead storage and unavailable for use.

Figure 10 Dugout Size vs. Available Water



Runoff volume is determined by the amount and timing of snowmelt or precipitation, plus vegetation, soil type, soil moisture, and topography. The smaller the quantity of runoff expected in an area, the larger the contributing area must be to fill a dugout. In some dry regions of southeastern Alberta and southwestern Saskatchewan, more than 2000 acres of land are required to produce enough runoff to fill a dugout with a capacity of one million Imperial gallons. In wetter areas of southeastern Manitoba, less than 25 acres would be required to supply the same volume.

Figure 11 Runoff Map shows the approximate area of land required to provide runoff water volume equal to or greater than one million Imperial gallons. Runoff varies a great deal from year to year. The map is based on long term runoff data. In eight out of every ten years, the specified amount or more runoff occurred. In two out of ten years, there was less runoff. The uncertainty of runoff should be kept in mind when planning dugout size. If a particular watershed is too small to provide enough runoff, you have two choices:

- Find a larger watershed.
- Find an additional watershed and build a second dugout.

When faced with these choices it is a good idea to consult a water specialist. Evaporation rate is an important factor in dugout sizing that varies widely between regions. Figure 12 Evaporation Zones is a map of evaporation loss zones on the Prairies. The greater the evaporative losses, the greater the storage volume must be to guarantee continuous supply.

The shape of a dugout has important implications for both the quantity and quality of the stored water. Historically, most dugouts have been about 12 feet deep. However, new larger structures are being excavated to depths of 15, 18, and 21 feet and even deeper.

A deeper dugout is more efficient because it has less surface area for the same capacity, and thus loses less water to evaporation. This can have a significant effect on the required volume. For example, in Evaporation Zone 4, a 21 foot-deep dugout can be constructed with approximately two thirds the volume of a 15 foot deep dugout and provide the same amount of available water. Deeper dugouts tend to have better water quality, particularly in winter. Three main concerns with deeper dugouts are high water tables, seepage losses, and increased safety hazard.

During winter, dugouts freeze and some of the stored water becomes unavailable for use. Ice can reach up to 2 to 3 feet in thickness, which may represent up to 20-40% of total volume. Figure 10 shows the amount of stored water that becomes unavailable for use during winter.

Figure 11 Runoff Map

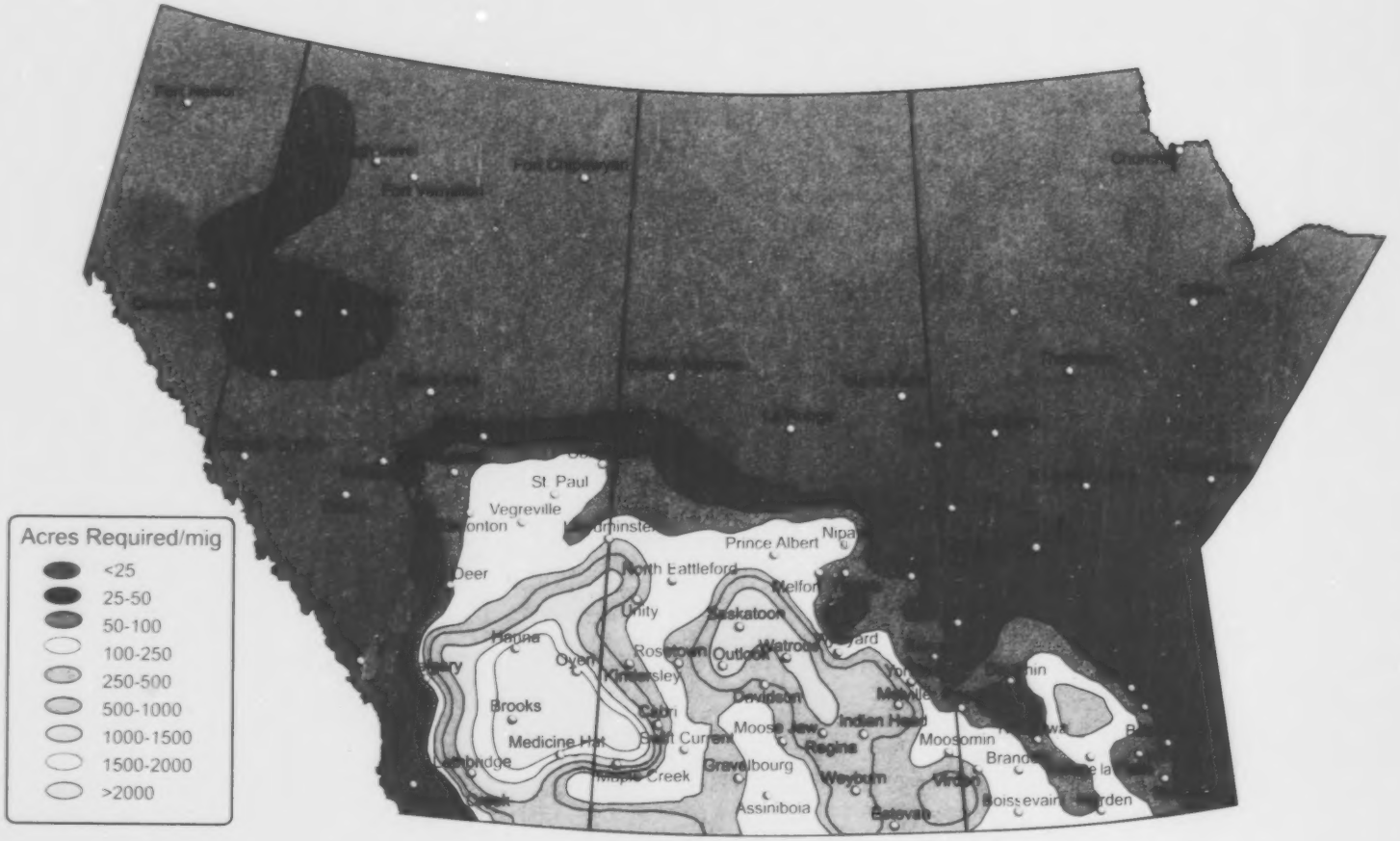
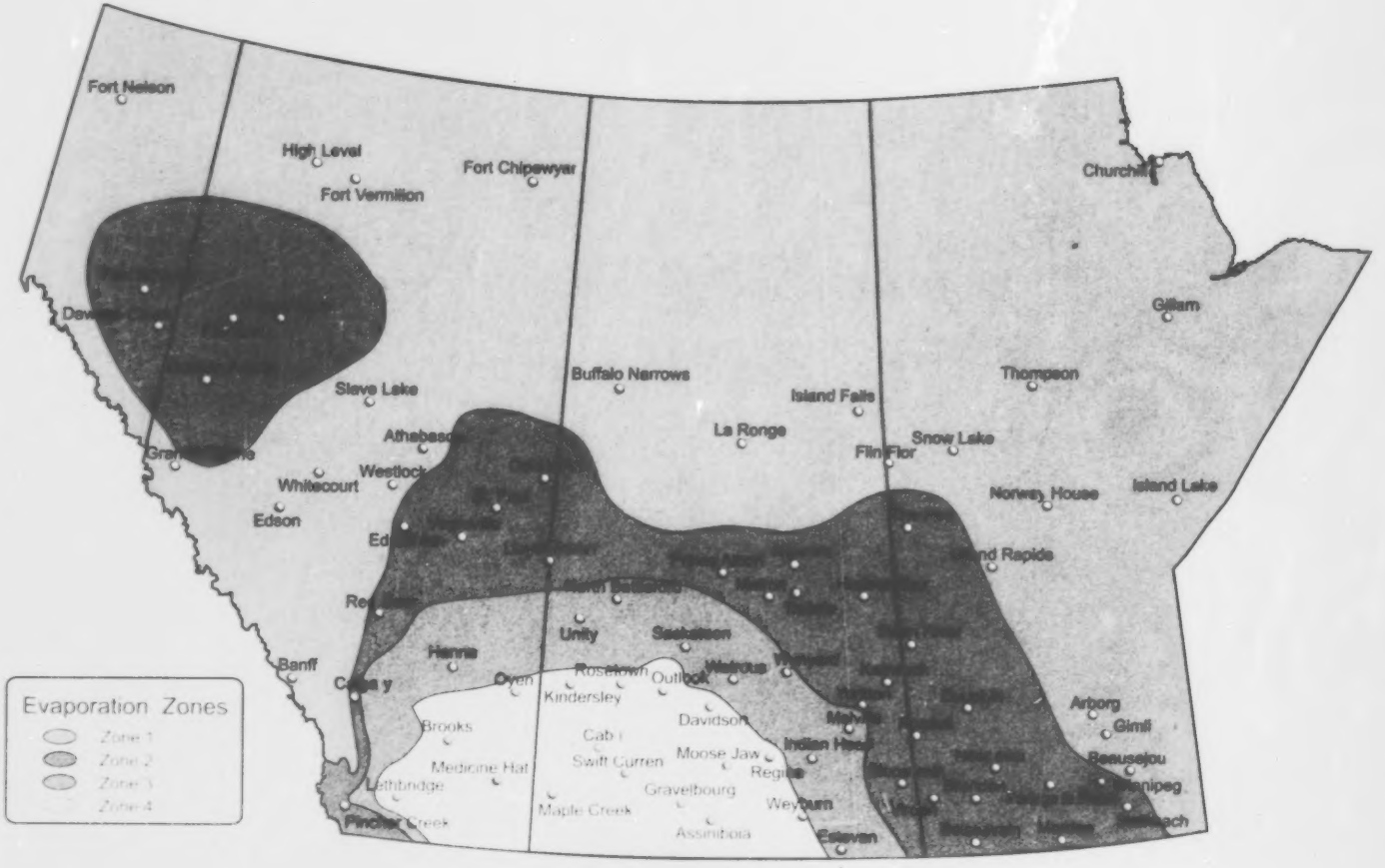
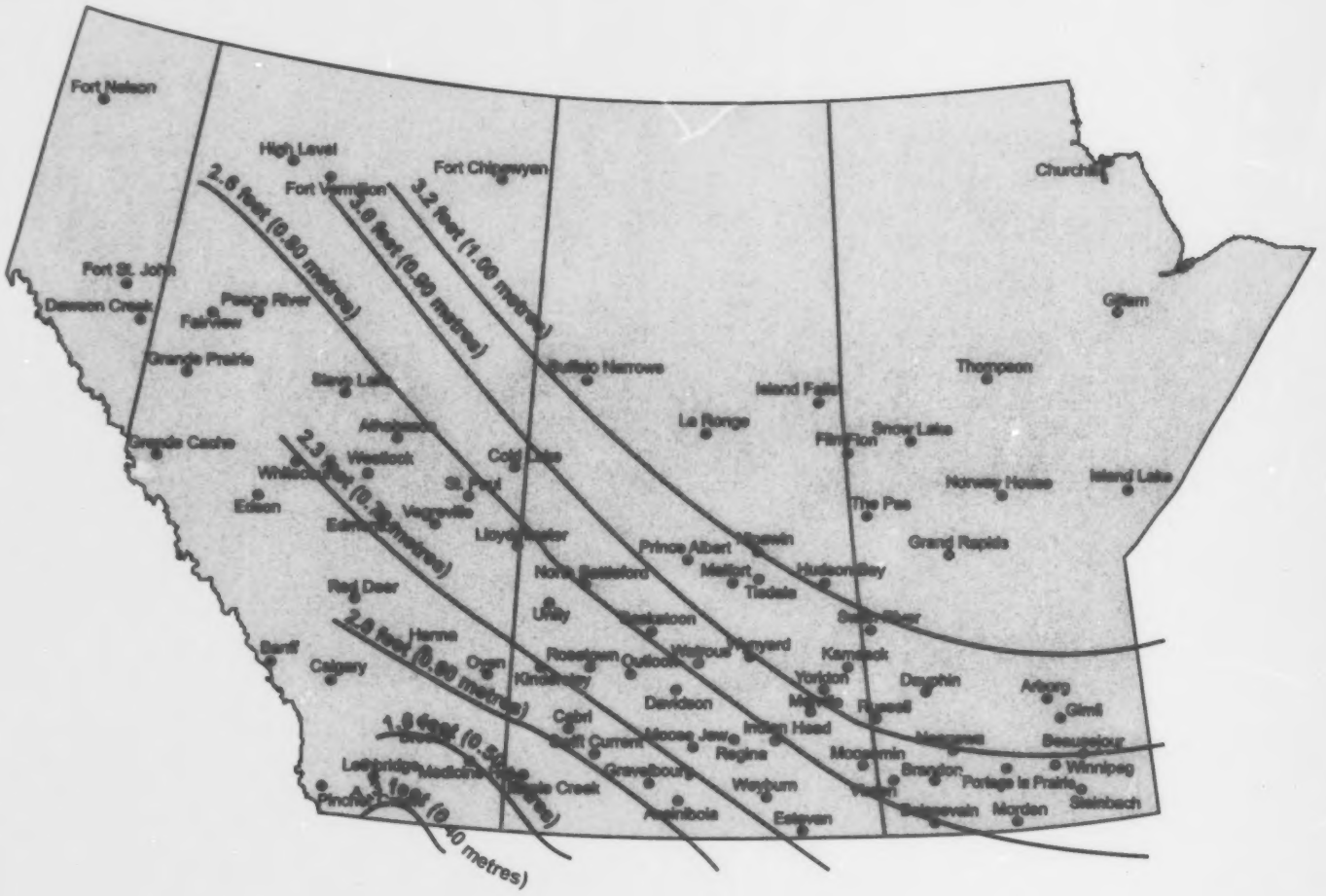


Figure 12 Evaporation Zones



In general, the colder the climate the thicker the ice, and the greater the loss of available water. However, this can be offset by differences in snowfall. Snow cover on the ice insulates the water from further freezing. Figure 13 Ice Thickness Map shows average expected ice thickness on small water bodies in different parts of the Prairies.

Figure 13 Ice Thickness Map



The climate and runoff information given previoiusly is used to plan the size of a dugout for any location on the Prairies.

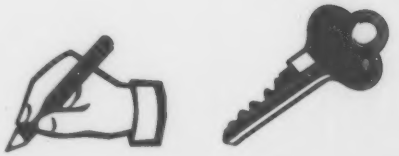
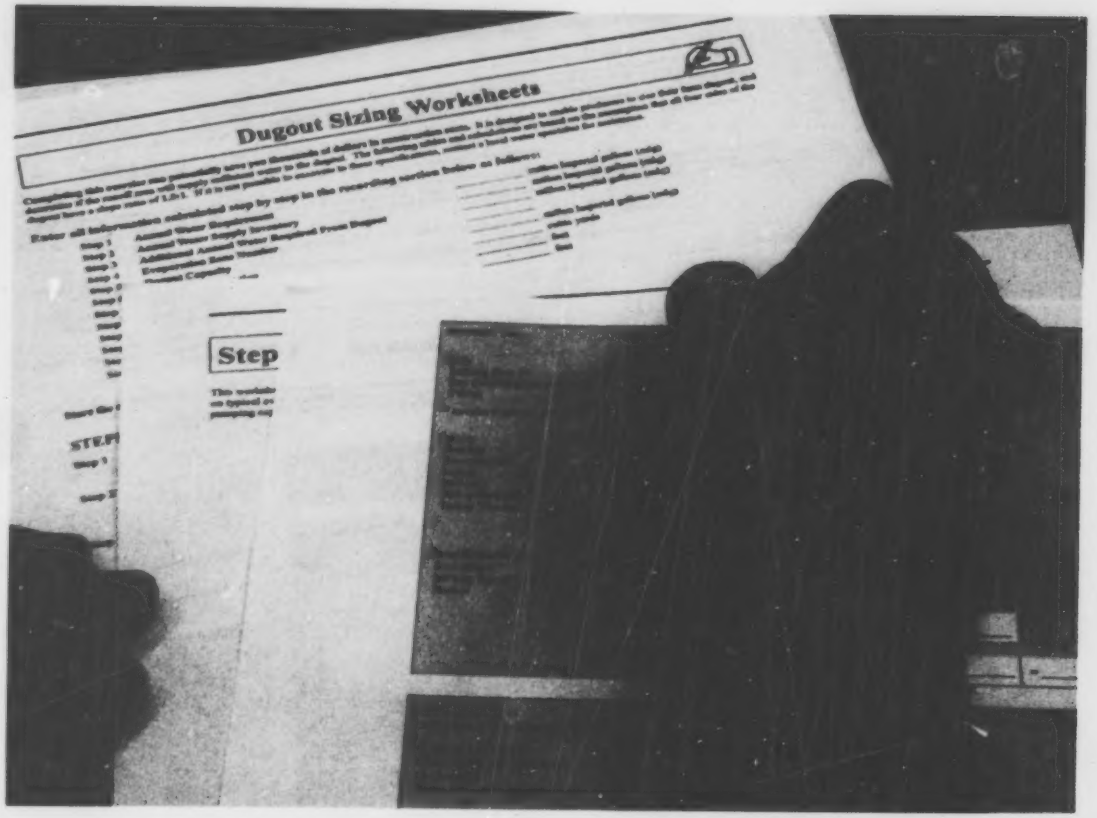


Figure 14 Dugout Sizing Example illustrates an example of the dugout sizing process for the Joe Agricola Family Farm at Kindersley, Saskatchewan. Remove the completed example from the pocket inside the front cover of the manual and work through it. **Completing this exercise can potentially save you thousands of dollars in construction costs.** Carefully follow the steps and calculations to understand the process. Blank forms for accurately sizing your farm dugout are located in the pocket inside the back cover of the manual.

Figure 14 Dugout Sizing Example



Water Quality and Watershed Management

Good watershed management is the first line of defense for ensuring good quality, dugout water. Using what are termed Best Management Practices or **BMPs** within the catchment or runoff area can minimize the possibility of dugout water contamination. Contamination occurs through a number of processes.

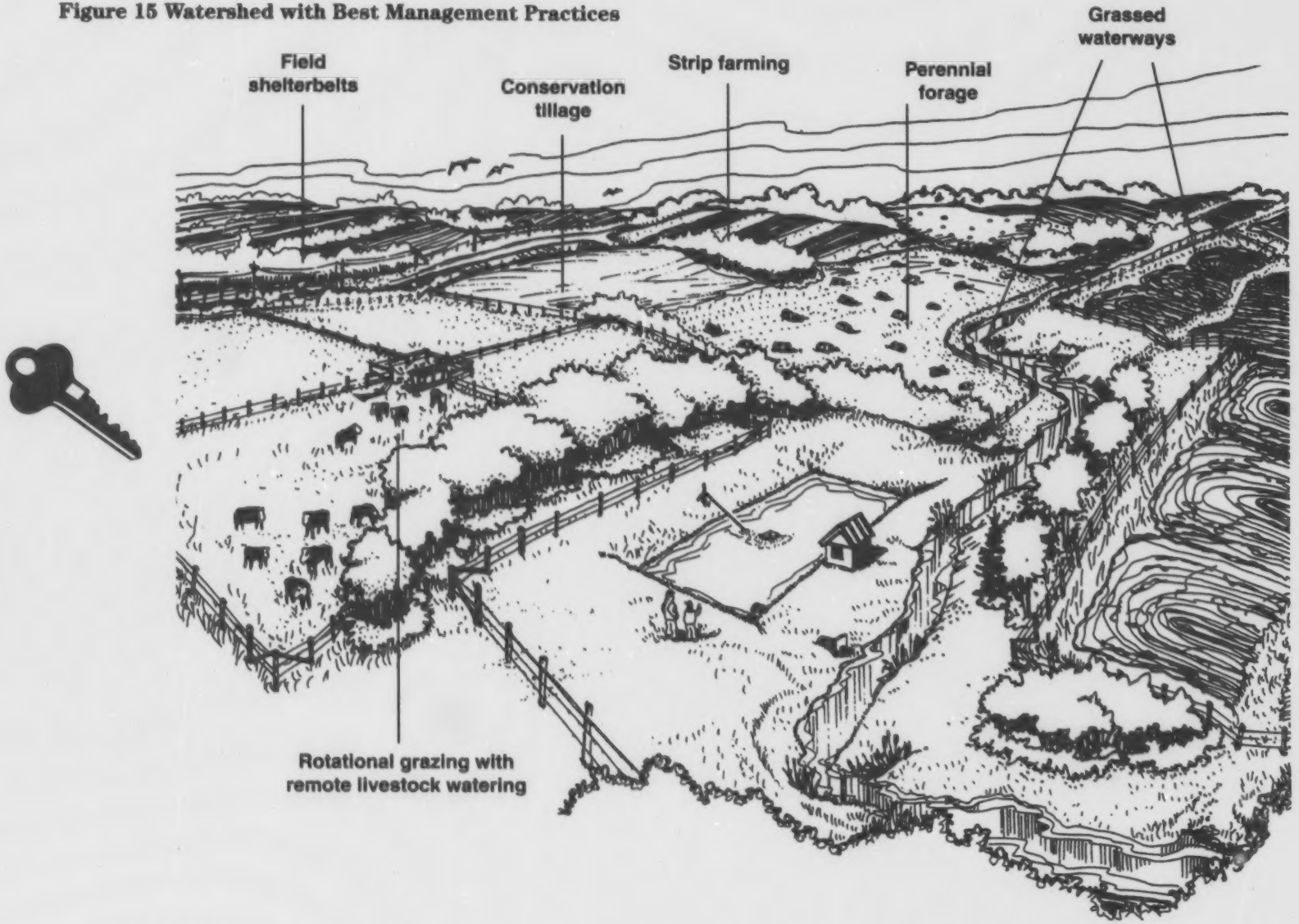
- Plant nutrients from natural sources, fertilizers, and manure entering a dugout in field runoff stimulate the growth of plants and algae.
- Pesticides can contaminate water when stored improperly, mixed carelessly, or spilled. They can also be present in runoff water from recently sprayed fields. Airborne drift clouds are able to travel long distances and may be deposited in streams, lakes, and dugouts.
- Runoff from livestock confinement areas is typically rich in nutrients and likely contaminated with bacteria, viruses, and parasites.
- Poorly sited waste disposal sites or inadequate storage facilities can contribute fuels, paints, solvents, and other hazardous chemicals to dugout in-flow water.
- Water erosion loads runoff water with soil, nutrients, and pesticides that may end up in dugouts. Long, steep slopes in the landscape, that are not under perennial cover, are very susceptible to water erosion events. Even relatively level fields can be subject to severe water erosion during spring runoff and heavy rainfall events. Silty soils are particularly susceptible to water erosion. Suspended solids in runoff water cause turbidity in dugouts, causing problems in water distribution systems and increasing the difficulty and cost of treatment.
- Wind erosion may lead to contamination of dugouts when soil is blown into the water from adjacent fields or livestock areas. Sandy soils and heavy clay soils are most susceptible to wind erosion.

Best Management Practices in a Watershed

The following BMPs can reduce erosion and contamination of inflow water as illustrated in Figure 15 Watershed with Best Management Practices:

- Agricultural fields in annual cultivation are prone to wind and water erosion, particularly when residue cover is poor in winter and early spring. Soil surface protection practices are highly effective ways of preventing erosion:
  - Seeding erodible land to perennial forages
  - Using conservation tillage
  - Maintaining crop residues in the fall
  - Using winter cover crops
  - Using crop rotations that follow low-residue crops with those with higher straw-yield.
- Practices that slow water runoff velocity and reduce water erosion:
  - Grassing waterways
  - Contour planting placing rows perpendicular to the slope of a field.
- Practices that slow wind velocity and reduce wind erosion:
  - Strip farming consisting of alternating bands of annual and perennial crops.
  - Planting and maintaining shelterbelts.
- The amount of fertilizers applied in a watershed can be minimized by proper nutrient management planning. Nutrient management is based on application of only enough fertilizer to make up the difference between the amount available in the soil and the crop requirement.
- Total amounts of pesticides applied to a watershed can be minimized through the principles of **integrated pest management** or "IPM". IPM is a pest management system using the application of a variety of management practices and control measures.
- Remote watering systems prevent livestock from having direct access to a dugout, or to other areas in the watershed that directly contribute runoff to a dugout.
- Good manure management protects water from contamination. As with chemical fertilizers, manure should not be applied in quantities that provide plant nutrients in amounts that exceed crop requirements.
- Good livestock management prevents over-grazing, which can leave soils susceptible to erosion. This can be prevented by using a rotational grazing system.

Figure 15 Watershed with Best Management Practices



Dugout Siting

Locating a dugout to collect enough water is of primary importance, but there are other factors to consider when planning the location.

Proximity to Water Use

By locating a dugout close to places where the water will be used, construction and maintenance costs of water lines and power pumping costs can be minimized.

Proximity to Electrical Power

Most water delivery systems have the pump near the dugout. Nearby electrical power reduces costs for extending power lines. Ready access to power also allows for easy installation of an electric aeration system.

Trees

Properly placed trees can act as snow traps and increase the amount of runoff collected each spring. However, trees close to the dugout tend to block the wind and reduce the positive effects of wind on the mixing of dugout water. Trees also reduce the effectiveness of any windmill-driven mixing devices. Leaves and twigs that are dropped by trees and deposited into dugout water add organic matter and plant nutrients that encourage weed and algae growth and reduce water quality. Large trees planted close to a dugout can use much of the stored water if their roots can reach the reservoir. It is recommended that deciduous trees be planted no closer than 160 feet (50 meters) and coniferous trees and shrubs no closer than 65 feet (20 meters).

Proximity to Other Water Sources

If possible, locating a dugout near another water source is advisable. Dugout water quality can sometimes be improved by pumping water into a dugout from another source such as a creek or slough.

Contamination

Avoid sites that could be affected by contaminated runoff or leaching:

- manure storage areas
- animal confinement areas
- waste disposal sites
- pesticide and fertilizer storage areas
- septic fields
- commercial and industrial sites.

Design and Construction

Dugout Design

The construction and management of a dugout can have a large impact on water quality. Design options allow dugout owners to control inflow and permit only the highest quality water to be stored. Once runoff has been collected, good management can prevent water quality from deteriorating as illustrated in Figure 16 Dugout with Design Best Management Practices.

Slopes

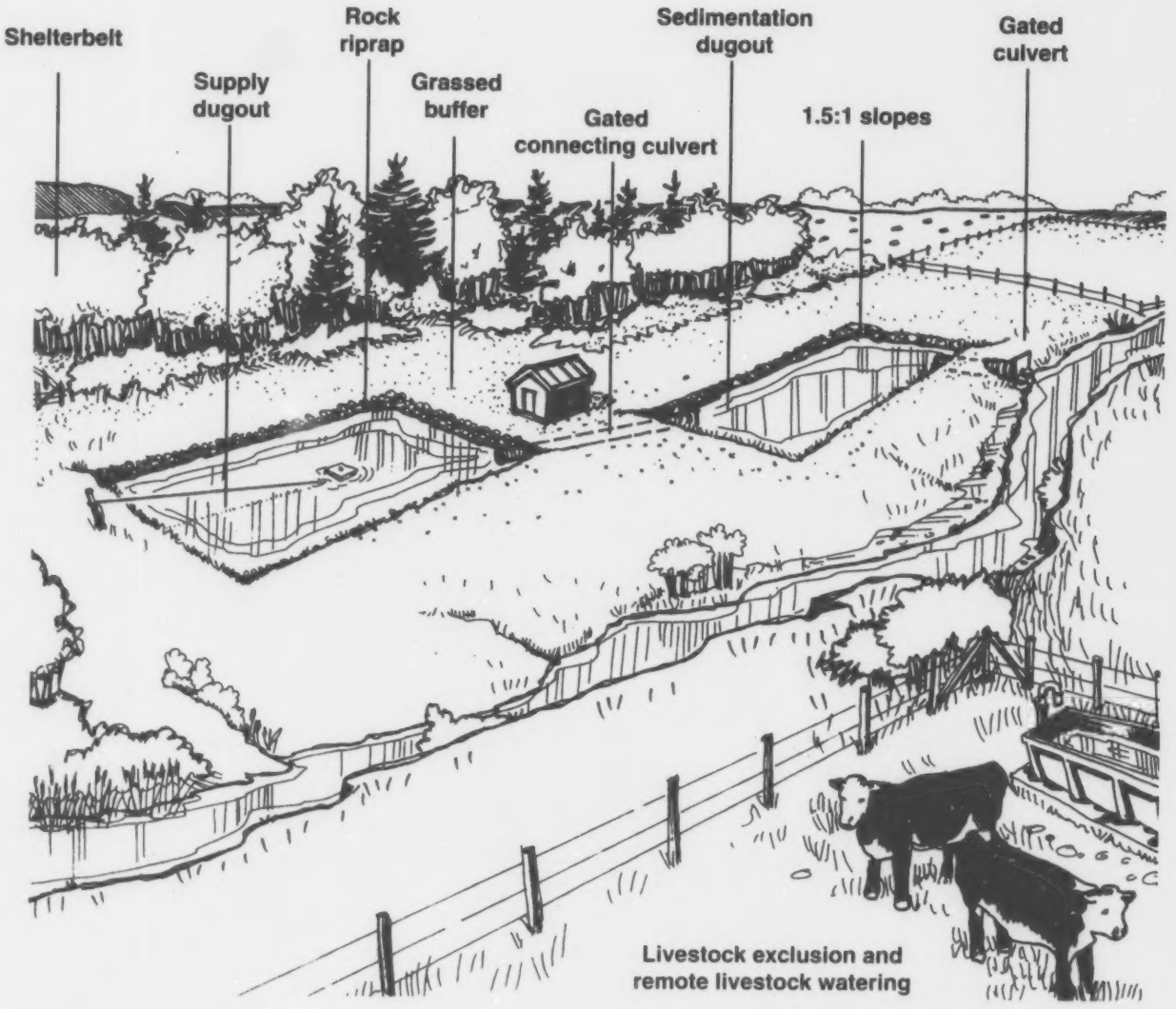
Historically, dugouts on the Prairies were constructed with 1.5:1 side-slopes and 4:1 end-slopes. The soil conditions and the construction equipment available largely dictated these specifications. Equipment capable of digging deeper excavations with steep end-slopes is now readily available. Steeper slopes reduce the growth of cattails and other aquatic plants that contribute organic matter and plant nutrients to the water. However, a dugout with four steep sides can be a safety hazard. It is recommended that dugouts be fenced to exclude livestock, and a flotation device should be available and used to protect children and adults from drowning.

Erosion Control

Spoil piles are created during the construction of a dugout. If spoil piles are located at the edge of a dugout, they may erode or slump into the water. Spoil piles may also act as a windbreak and reduce wind mixing which incorporates oxygen into the water. It is recommended that the spoil piles around a dugout be leveled to maintain bank stability, and grassed to provide a filter that reduces the entry of soil and nutrients. Although the ideal width of a grassed buffer varies between sites, the recommended **minimum** is 10 meters.

In windy areas of the Prairies, dugout life is increased when the dugout sides and end slopes are protected to prevent soil erosion by wave action. This can be done with a combination of grass, rocks (often termed **riprap**), heavy plastic, or **geo-textile** materials. Riprap can also be effective at discouraging muskrats from moving in.

Figure 16 Dugout with Design Best Management Practices



Inlet Structures

A dike and gated culvert inlet can be built to give the owner control over the inflow water. Poor quality water can be prevented from entering a dugout. The first flow of water from cultivated fields during snowmelt is typically high in dissolved nitrogen and phosphorus. Excluding this initial volume of water can improve water quality. Diverting flow away from the dugout is only practical where it is certain that there is more than enough runoff to fill the dugout. After the dugout has filled, the inlet should be blocked. This prevents sediment and nutrients carried by runoff from spring and summer rains from entering the dugout. If water is pumped into a dugout, prevent bank erosion from occurring at the discharge point.

Livestock Exclusion

Allowing animals to water directly from a dugout degrades water quality and drastically shortens the life of a dugout. Nutrients from manure stimulate plant growth and hoof action destroys dugout banks. It is recommended that all dugouts be fenced off and water supplied to livestock through remote watering systems. This protects the dugout, its water quality, and the livestock themselves. Many options are now available for supplying water to livestock on remote sites. Where a dugout is far from electricity, alternative power sources including windmills, solar panels, gravity systems, and animal powered devices, such as "nose pumps", are reliable and affordable options.

Sedimentation Dugouts

Much of the unwanted material that enters a dugout in runoff is suspended. If water is allowed to stand, much of the suspended soil and organic matter will sink to the bottom. In locations where the soil is highly erodible, and the landscape and costs permit, two dugouts can be constructed adjacent to one another. The first will act as a settling pond. High quality, surface water can then be either pumped into the supply dugout or allowed to flow in by gravity.

In a situation where an existing dugout is being replaced with a new one, it may be useful to retain the original as a sedimentation structure. The new dugout can often be positioned to fill with water that has been allowed to settle in the old dugout. This can be more beneficial and economical than cleaning out the original dugout.

Dugout Construction

Pre-Construction Testing

In many areas of the Prairies, sand, silt, and gravel layers occur close to the soil surface. Many of these layers can contain small amounts of groundwater that has seeped down from the surface. While many people installing new dugouts believe it is good to have water seeping into the dugout, these lenses of sand and silt can create many problems. They may provide a path for water to seep out of the dugout leading to depleted water supplies during periods of drought. In addition, highly mineralized groundwater seeping into the dugout can adversely affect the quality of trapped runoff water.

To ensure that sand lenses are avoided, dig at least five or six test holes or pits prior to excavating the dugout. Dig these holes around the outside and within the proposed dugout area to a depth of 4 to 5 feet (1.2 – 1.5 m) deeper than the proposed dugout bottom. They should not be located more than 100 feet (30 m) apart to minimize the possibility of missing intermittent sand layers that may occur. This testing will also identify other problems including shallow water tables and bedrock, as well as the most suitable construction equipment.

Large Scale Sealing Methods and Materials

If sand layers are generally in the area and no suitable site can be found, several additional test holes or pits may be required to determine the extent of the sand layers and help determine how to seal these areas. In some cases, it may be best to abandon the site and try to locate a dugout in more favourable soil conditions. In other cases, it may be simply a matter of over-excavating the areas of concern and backfilling with expanding clay to provide the proper seal.

For larger areas, the potential for seepage must be addressed at the time of construction. If it appears that seepage will be a problem, then most sealing methods will require flatter slopes of approximately 3:1 for the sealing treatment to be applied. Consult a professional soil or water specialist if large-scale sealing is required.

Clay Lining

If a source of good heavy clay is available, it may be feasible to haul and spread the clay into the problem areas and use packing equipment to pack the material into place to form an

Figure 17 Footed Drum Packer

impermeable layer. The packing of the clay is normally carried out with specialized equipment known as "sheepsfoot" or "footed drum" packers, as shown in Figure 17 Footed Drum Packer, which are capable of exerting extreme pressures to compress the material into impervious layers. Care must be taken to compact the material in thin layers of not more than six inches (15 cm) thickness each time to ensure proper compaction is achieved. In dry soil conditions, water must be added to achieve proper compaction. Generally, six passes with a packer will achieve the proper mixing and compaction for a good seal. The thickness of the clay liner that will be required depends on the clay, but should be at least one and one half to three feet thick (45 – 90 cm).

Bentonite

Bentonite is a highly expandable clay that is mixed with the soil and packed into place to seal the excavation. Once the dugout fills and the bentonite becomes wet, it expands and provides a very impervious seal.

Sodium Chloride

If the clay content of the soil is in excess of 20%, a sodium-bearing compound such as sodium chloride can be incorporated into the soil to produce a seal. If this practice is to be followed, soil tests are required to determine the clay content and the amount of sodium compound required.

Plastic Liners

While plastic liners are available to prevent seepage, they are expensive and must be installed according to the manufacturer's instructions. Some plastic liners are ultraviolet light protected and have a 10-year guarantee. For plastic liners to last longer, they must be either thicker or covered with a sand layer. To place a sand layer on a plastic liner requires a low slope. Any tears in the liner can cause it to fail. In certain cases, air trapped under the liner can float it to the water surface. For high water table conditions, drains must be installed to lower the water table. This will prevent ground water pressure from below, lifting and floating the liner.

Gleization

In place of the traditional methods of sealing porous soils, a dugout can be sealed using a method called **gleization**. This involves covering the dugout bottom with 6 inches (15 cm) of chopped straw. The straw layer is then covered with 6 inches (15 cm) of clay and compacted into place. As the straw decomposes under low oxygen or anaerobic conditions, a rubbery blue-

grey substance is produced that seals the pores between the soil particles. Since bacteria are breaking down the organic matter, the seal takes time to develop. Water will seep out while the seal is forming.

Perimeter Trench

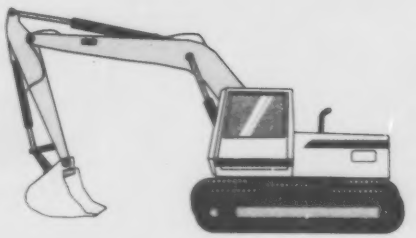
If the sand and gravel lenses are only located in the upper portion of the excavated area, a cut-off trench can be installed. The trench should be dug as deep as the bottom of the dugout and be extended around the total perimeter of the excavation. The trench is then filled and packed with good clay to form a perimeter seal. If the existing soil is generally high in clay content with only minor layers of sand and gravel, the material excavated from the trench can be mixed up and packed back into the trench. Since the lenses of sand and gravel are no longer continuous, the dugout will hold water. If good clay is not readily available, a cutoff curtain made of woven polyethylene fabric can be installed.

Excavating Equipment

Trackhoe

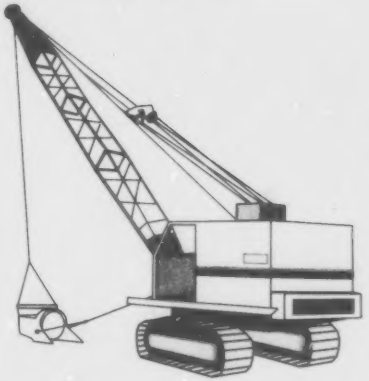
A trackhoe as shown in Figure 18 is a large backhoe mounted on caterpillar-type tracks for maneuverability and flotation. Due to availability, ease of operation, versatility, and speed and ease of transport, the use of trackhoes for digging dugouts has increased dramatically. Since these machines are very fast, they can remove large quantities of earth in a very short time. Also, they complete all the work from the top edge of the dugout, and do not need to crawl in and out of the excavation. Trackhoes are able to excavate the end slopes of the dugout to the same angle as the sides. They have a distinct advantage for excavating wet materials.

Figure 18 Trackhoe



The main disadvantage of this type of unit is the reach of the boom, and consequently the width of the dugout that can be conveniently built. Some of the newer units, with extended booms, are able to dig dugouts 60 to 70 feet (18 to 21 meters) in width. Due to the shorter reach, the soil removed is piled very close to the edge of the dugout. This can lead to collapse of the banks due to the extra weight of earth. Because it is impractical to move and spread the excavated material with a trackhoe, the spoil pile presents a problem. For wider and deeper dugouts, the trackhoe can move the excavated material a second time. A better option is to use a dozer or a large loader to move the piles of excavated soil back away from the edge of the dugout. The fill can be used in low areas or to establish dikes to control the flow of water.

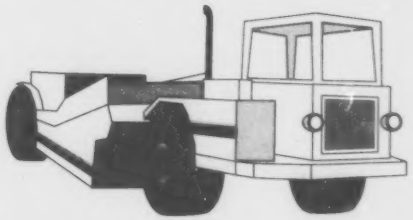
Figure 19 Dragline



Dragline

While the dragline shown in Figure 19 has been around for many years, its use in digging dugouts has declined in recent years due to the difficulty of transporting it. It is slower and less versatile than a trackhoe. Due to long reach and flotation, the dragline is ideally suited for installing dugouts in swampy or low-lying areas. Draglines can excavate dugouts up to 70 feet (21 meters) in width. In addition, because of the reach, spoil banks can be kept away from the edge of the dugout but, as with the trackhoe, it is impractical for the dragline to move and spread the excavated material to other areas.

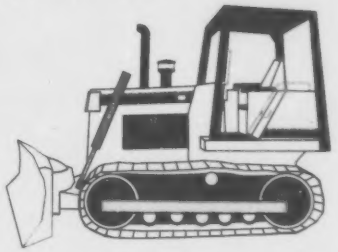
Figure 20 Scraper or Buggy



Scraper or Buggy

Scrapers or buggies as shown in Figure 20 are large units that are used to remove, carry, and deposit the earth from the dugout excavation. Buggies are mounted on rubber tires and have the advantage of being able to move large amounts of earth very quickly. They can easily move the material to other areas for landscaping and diking purposes. As the hole becomes deeper, and the soil more compacted, this type of unit may encounter problems with traction and in some cases may require a cat with a ripper tooth to loosen the soil before excavation. Track-type scraper units are slow but have better traction and can work in more varied soil conditions. The main disadvantage of these units is the need for gently sloping end-slopes to allow entry and exit from the excavation. It is recommended that these flat slopes be steepened with a trackhoe.

Figure 21 Dozer



Dozer

While a dozer as shown in Figure 21 can excavate a dugout alone, it is a slow process and will result in large spoil piles at both ends of the dugout. Wet soil conditions can cause delays and problems for a caterpillar. However, due to its traction, it can operate in a variety of soil types. As with other scraping equipment, dozers cannot construct steep slopes on all sides. Gently sloping end-slopes are required for entrance and exit from the excavation. The end-slopes should be steepened with a trackhoe.

Selecting a Contractor

Experience

While digging a dugout may sound easy, how it is built will determine how long it lasts and how well it performs. For example, the slope of the sides will depend largely on soil type. The more silt or sand a soil contains, the flatter the slopes must be in order to prevent collapse. Similarly, sandy pockets or veins encountered during excavation may require sealing to prevent future leakage. An experienced contractor will recognize soil problems and inform the land-owner of possible solutions. Further technical assistance can be obtained from a soil or water specialist.

A dugout is more then just a hole in the ground.

References

A good contractor should be willing and able to provide a list of past clients. These references should be checked to see not only if the previous clients were satisfied with the work completed, but also how the dugout is operating and if any problems have arisen due to construction techniques utilized.

Equipment

The availability of equipment in the area will be an important factor in choosing a contractor. The equipment to be used should not only appear to be in good mechanical shape, but must also be appropriate for the site. The choice of the wrong equipment can lead to a very expensive dugout and one that may not be completed to your satisfaction.

Dugout Finishing

It is recommended that excavated material from the dugout be leveled, spread, and topsoil replaced. The final steps are to install any culvert inlets and trenches for water and airlines, replace the topsoil, and seed grass to a buffer area around the dugout and the in-flowing runoff channels.

Costs

There is not a great deal of difference in cost between various types of excavation equipment. However, to ensure the best price available, quotations should be obtained from several contractors whenever possible. Quotations are normally given in price per cubic yard or cubic meter of material removed. If the excavated soil is to be moved and spread to fill in low areas or form dikes, the cost should be kept separate from the dugout quote. As with any quote for work, it should always be in writing to eliminate any misunderstandings. Check to see if equipment transportation costs are included in the quoted price. Depending on the type and location of the equipment, transportation costs may be a major addition to the costs of excavation.

Time Factor

As with any type of contracted work, acceptable times for starting and finishing the job should be spelled out before any contracts are signed or work started. In many cases, availability of equipment will be the determining factor as most contractors are extremely busy in the fall of the year. Better prices may be possible if the work can be done in early summer, during the "off season".

Construction Estimate

The first step is to get two or three dugout construction estimates. A sample construction estimate is provided in Figure 22 to illustrate the important information that should be obtained from a contractor. All agreements for work should be in writing and signed by both parties. Written contracts help eliminate any misunderstandings as to specifications, timing, and costs. The example is based on the Joe Agricola farm dugout that was used in the Planning Module as an illustration of the use of the Dugout Sizing Worksheets. Carefully read through the completed example. A blank copy of the Dugout Construction Estimate is included in the pocket at the rear of the manual.

Figure 22 Construction Estimate

Dugout Construction Estimate Worksheet

This worksheet lists the items that a producer should discuss with a dugout construction contractor. A clear understanding between both parties is crucial so there are no misunderstandings or false expectations. Dugouts are far more than a deep wet hole in the ground.

Dugout Owner: *Joe Agricola*
Address: *Kindersley, Saskatchewan*

Dugout Contractor: *Dugouts R' Us*
Address: *Kindersley, Saskatchewan*

Dugout Location: Qtr *NE* Sec *12* Twnshp *40* Range *30* Meridian *W3*

Proposed Starting Date: *October 15, 2001*
Proposed Completion Date: *October 22, 2001*

Proposed Dugout Use: Household *X* Livestock *X* Irrigation _____ Recreational (i.e., fish) _____ Other _____

Check Location of Underground Utilities: *Contact utility company to mark lines October 7, 2001*

Pre-construction testing; Test hols or test pits to identify otential problems
including sand or gravel (i.e., seepage), high water tables, or shallow bedrock No. of test holes or pits *2* Depth of testing: *25 ft.*

Design Considerations for Dugout: Depth *21 ft* Width *100 ft* Length *330 ft* Volume *16,000 yd³* Side slope *1.5:1* End slope *1.5:1*

Runoff or Flood Control: *A dike will be constructed around the dugout with a gated inlet to control runoff into the dugout.*

Seepage Control or High Water Table Conditions: *None expected – testholes will confirm.*

Types of Construction Equipment: Trackhoe *$100/hr* Dozer *$80/hr* Scraper _____ Dragline _____ Buggy _____ Other _____

Equipment Transportation Costs: *0.00*

Dugout Construction Costs:

(a) pre-construction testing	$ *100.00* /hour	x	*2*	hours	= $ *200.00*
(b) stripping top soil	$ *80.00* /hour	x	*2*	hours	= $ *160.00*
(c) excavation costs	$ *1.00* /hour	x	*16,000*	yd³	= $ *16,000.00*
OR					
(d) seepage control	$ _____ /hour	x	_____	hours	= $ _____
(e) spread excavated material	$ _____ /hour	x	_____	hours	= $ _____
(f) dike and gated culvert inlet (i.e., flood control – optional)	$ *80.00* /hour	x	*10*	hours	= $ *800.00*
(g) trenching water and air lines and install wet well	$ *100.00* /hour	x	*1*	hours	= $ *100.00*
(h) topsoil replacement	$ *100.00* /hour	x	*2*	hours	= $ *200.00*
(i) topsoil preparation and seed to grass	$ *80.00* /hour	x	*2*	hours	= $ *160.00*
					= $ _____

Transportation and Construction Costs $ *17,620.00*

Tax $ *1,233.40*

Total Cost $ *18,853.40*

Payment Schedule *Within 30 days of dugout completion*

Figure 22 Construction Estimate

Dugout Construction Estimate Worksheet

This worksheet lists the items that a producer should discuss with a dugout construction contractor. A clear understanding between both parties is crucial so there are no misunderstandings or false expectations. Dugouts are far more than a deep wet hole in the ground.

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Proposed Dugout Use: Household *X* Livestock: *X* Irrigation ____ Recreational (i.e., fish) ____ Other ____

Check Location of Underground Utilities: *Contact utility company to mark lines October 7, 2001*

Pre-construction testing: Test hole or test pits to identify potential problems including sand or gravel (i.e., seepage), high water tables, or shallow bedrock: No. of test holes or pits *2* Depth of testing *25 ft.*

Design Considerations for Dugout: Depth *21 ft* Width *100 ft* Length *330 ft* Volume *16,000 yd³* Side slope *1.5:1* End slope *1.5:1*

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Types of Construction Equipment: Trackhoe *$100/hr* Dozer *$80/hr* Scraper ____ Dragline ____ Buggy ____ Other ____

Equipment Transportation Costs: *0.00*

Dugout Construction Costs:

(a) pre-construction testing	$ *100.00*	/hour	x *2*	hours	= $	*200.00*
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OR						
(d) seepage control	$ ____	/hour	x ____	hours	= $	____
(e) spread excavated material	$ ____	/hour	x ____	hours	= $	____
(f) dike and gated culvert inlet (i.e., flood control – optional)	$ *80.00*	/hour	x *10*	hours	= $	*800.00*
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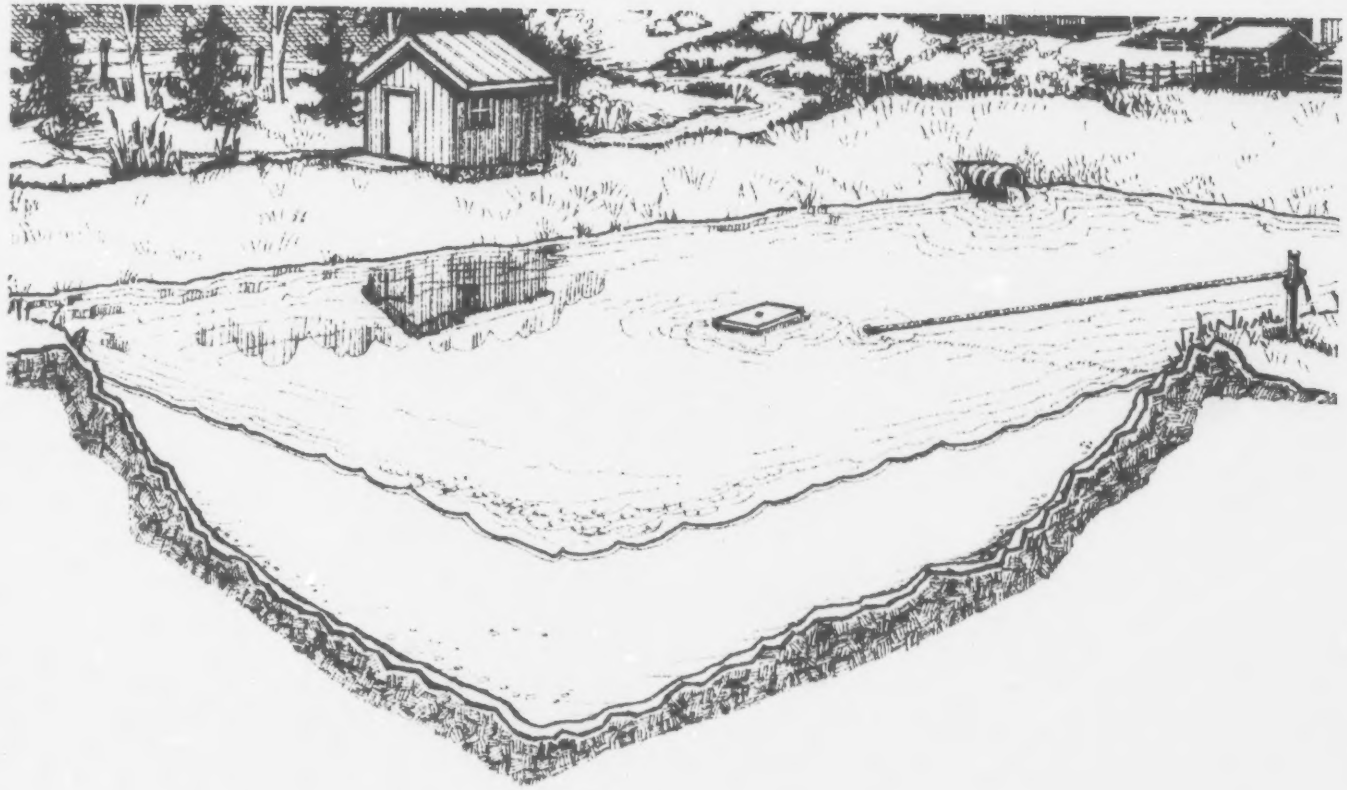
					= $	____

Transportation and Construction Costs $ *17,620.00*

Tax $ *1,233.40*

Payment Schedule *Within 30 days of dugout completion* Total Cost $ *18,853.40*

Operating Systems



Equipment Systems

A well-designed and efficient water system is a very important part of a farming operation. Dugouts are large reservoirs of water that can be pumped at a much faster rate than most wells on the Prairies. This is only an advantage if the water intake, pump, and water distribution lines are sized to meet the peak demands of the farm. Dugout aeration systems can make a dynamic improvement in dugout water quality. Remote watering systems that pump out of pasture dugouts help protect livestock from illness and injury as well as improve water quality and livestock production.

Intake Systems

Research has shown that water in the top four to five feet (1.2 to 1.5 meters) of a dugout is of higher quality than water at the bottom and edges of the dugout. It has also shown that many farm dugouts become depleted of dissolved oxygen resulting in black smelly water. For these reasons, floating, water intake systems are recommended for all farm dugouts.

Floating Intake Systems

For the past 20 years, floating, water intake systems have been used in dugouts. The floating intake draws the better quality water from near the dugout water surface. These systems are usually installed with a wet well beside the dugout which contains a submersible pump. However with jet pumps, the intake assembly hooks directly to the suction line, and a check-valve is installed next to the pump. This eliminates the need for a wet well. Whatever the chosen system, it is recommended that intakes be planned and installed at the time of dugout construction. Floating intake systems include the components shown in Figure 23 Floating Intake.

Figure 24 Submersible Pump and Intake System shows a submersible pump and intake system. Install the intake pipe inside another larger pipe where it enters the dugout. This will protect the intake line from possible damage or collapse during back filling of the intake pipe trench. The perforated intake pipe supplies water to a wet well located beside the dugout. The water flows by gravity as water is pumped from the well. Since plastic pipe is lighter than water, small concrete weights must be secured along the intake pipe. Generally, medium density 75 psi CSA rated pipe is recommended for the intake line. Install the dugout air line in the same trench as the intake line. This installation will protect the air line from freezing.

Figure 23 Floating Intake

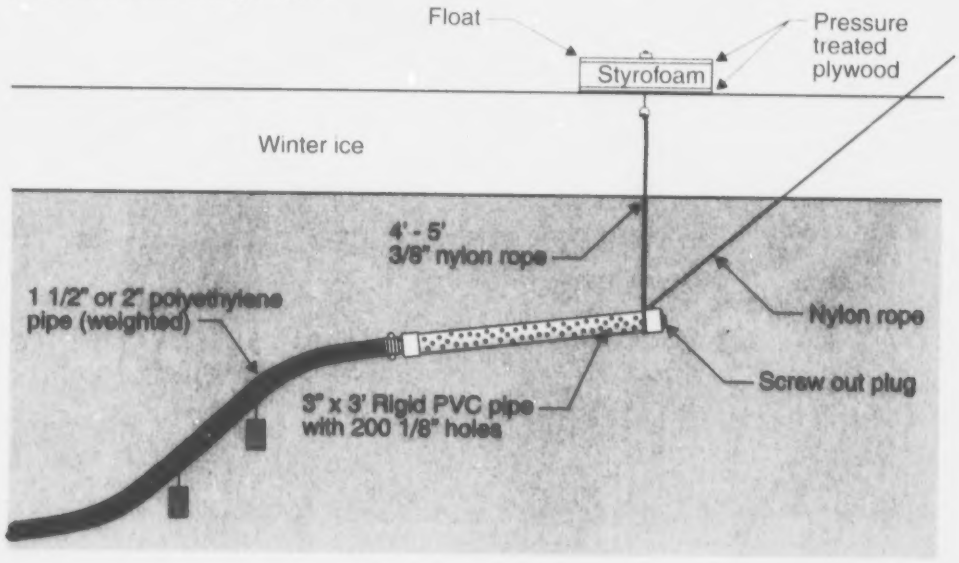


Figure 24 Submersible Pump and Intake System

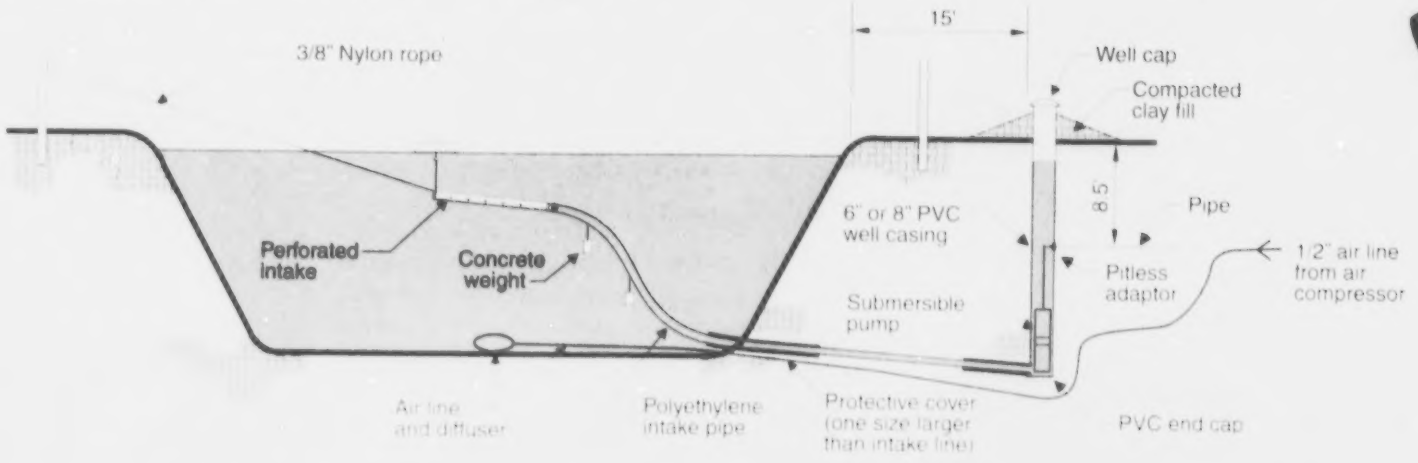


Figure 25 Plan View of Intake System

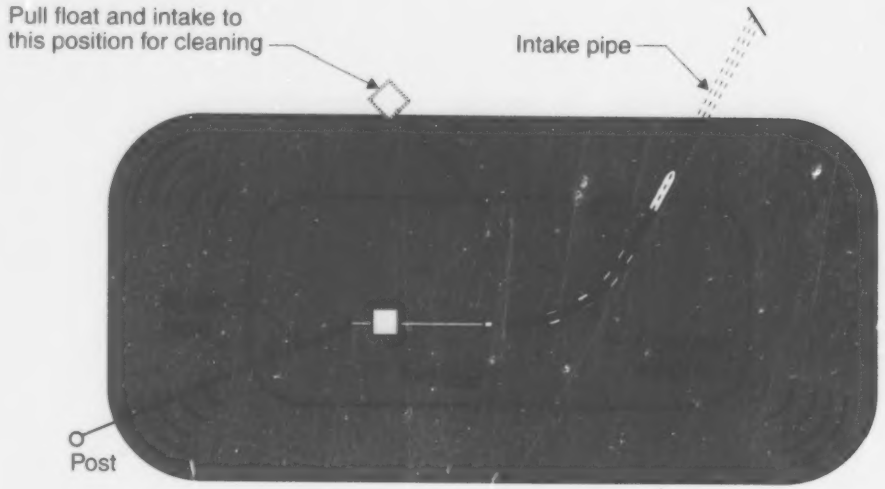


Figure 25 Plan View of Intake System shows a plan view of a dugout and the intake installation. The intake pipe should enter the dugout on a 45 degree angle to reduce the chances of kinking when the intake is pulled to shore for maintenance.

Other Intake Systems

Over the years, other types of water intake systems have been tried for dugouts. They are not recommended. Two common but unsatisfactory systems are:

Gravel infiltration trenches

Gravel-filled trenches between the dugout and a wet well beside the dugout have been unsuccessfully tried in the past. **They are not recommended.** The trenches can be effective filters for several years but will eventually fail due to plugging of the spaces in the gravel with soil, plant material, microorganisms, and biofilms. Flows to the wet well are inevitably reduced. Due to high levels of biological activity in the trench, oxygen levels fall which leads to the release of hydrogen sulphide gas. These conditions produce black smelly water in the wet well. It is also common to see a ten-fold increase in total dissolved solids, and greatly

increased problems with iron, manganese, and hardness due to leaching of dissolved minerals from the gravel material. The only solutions are re-excavation and replacement of the gravel every few years, or replacement with an intake pipe.

Dugout bottom intakes

Large 4 to 12 inch (10 to 30 cm) horizontal piping has been used to convey water from the bottom of the dugout to a wet well. Although these systems do not plug, poor water quality is a problem. Unless the dugout is continuously aerated, the poorest water quality is always near the dugout bottom. Large open-ended pipes often result in water bugs entering the wet well, pumps, and distribution system. In some cases, bugs can plug impellers on pumps and screens. Avoiding this problem requires installation of screens around the dugout intake or the pump intake in the wet well.

Wet Wells

A wet well is usually required beside the dugout to permit easy access to the pump. The water flows by gravity into the wet well as water is pumped from the well. For many years, two to three foot diameter, steel culverts were used for wet wells. Large diameter wells allow for some settling of solids to take place. However, recent monitoring of these installations has shown that dissolved oxygen levels are much lower in the wet wells than in the dugout water. The reasons for this include the large water storage capacity of wet wells and slow replenishment with fresh dugout water. Conditions in these wells can be similar to those that develop in gravel trenches: hydrogen sulfide gas formation, lower pH, and a high concentration of nutrients at the bottom of the wet well.

To avoid the problems associated with a large diameter wet well there are several options:

- Hire a vacuum-truck to come in every few years and suck out the black decayed plant material and sediment at the bottom of the wet well. It is very important that vacuum equipment be clean. A dirty hose can contaminate the well.
- For jet pump installations, elimination of the wet well is desirable with the intake assembly installed directly below the float in the dugout.
- For new submersible pump installations, a smaller diameter, 6 to 8 inch (15 – 20 cm) PVC well casing and pitless adapter are the best option. The smaller diameter PVC casing can also be installed inside an existing larger wet well. A smaller well has a steady supply of fresh dugout water and thus eliminates the poor water quality associated with larger wet wells. The PVC casing will last much longer than steel culverts, which eventually corrode.

Pumps

There are many types and sizes of pumps for dugout water systems. Some are designed for drawing from the water source only. Others draw the water and force it through the rest of the distribution system. Some pumps are used for special purposes such as boosting pressure or supplying a special outlet. Therefore, it is important to select the proper type and size of pump for the application.

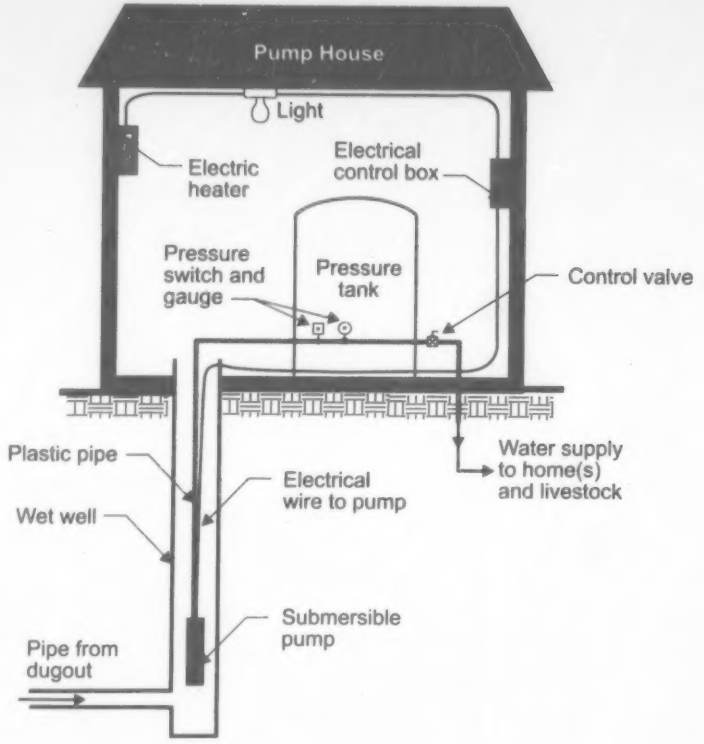
The most common pumps used for dugout applications systems are shallow well jet and submersible pumps. Shallow well jet pumps have a suction lift of approximately 20 vertical feet (7 m), including friction losses. Once water has been lifted to the pump, it can be pushed to higher elevations. Jet pumps can be installed away from the dugout in the basement of a house, heated shop, or pump house. Ensure that the suction line is adequately sized. Jet pumps require a larger intake pipe than submersible pumps but save the cost of running electrical power to the dugout. Jet pumps are not as efficient as submersible pumps and are more suited for supplying smaller volumes of water for rural residences.

A submersible pump can lift water hundreds of vertical feet. It operates like a shallow well pump but has a number of impellers or stages mounted close together on a shaft. Generally, because of the low lift required for dugout applications, a pump with six to ten stages or impellers will supply all the pressure required. The most common size of submersible pump is 4 inches (10 cm) in diameter. These pumps are available in 1/2, 3/4, and 1 horsepower and larger.

The pumps are placed in a wet well beside the dugout. Generally a small heated pump house is set over or beside the wet well to house the pressure tank, pressure switch, electrical controls, and any other dugout pumping or aeration equipment. See Figure 26 Submersible Pump, Wet Well, and Pressure Tank.

A rural water system requires a pressure tank. Pressure tanks store water and maintain water pressure between specified limits. As the water in the tank rises, air is compressed until the upper limit or cut out point is reached and pumping stops. When a valve is opened, the compressed air in the tank acts like a spring and forces water to flow into the system. Demands on the water supply cause the tank pressure to fall until the lower limit or cut in point is reached and the pump restarts. Without this buffer, the pump will start each time a small amount of water is drawn. Constant starting and stopping causes unnecessary wear on a pump. A 30 to 50 psi pressure switch is most common for farming operations.

Figure 26 Submersible Pump, Wet Well, and Pressure Tank

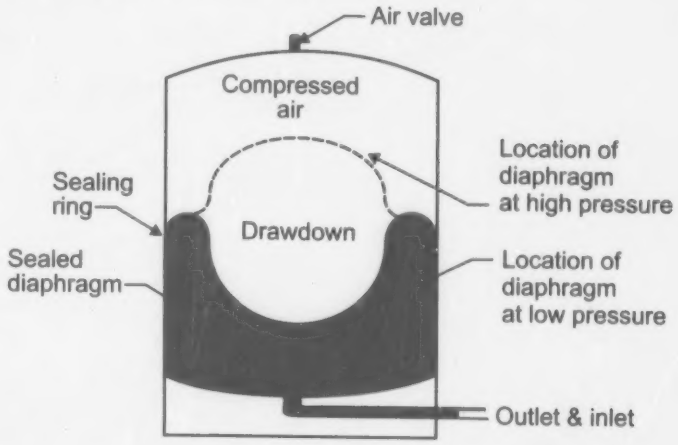


There are four types of pressure tanks:

- plain galvanized steel tank
- plain galvanized steel tank with floating wafer or disk
- diaphragm tank, pre-charged with air
- bladder tank, pre-charged with air.

For dugout applications, it is best to have a sealed air diaphragm or bladder tank for submersible pumps as shown in Figure 27 Sealed air Diaphragm Pressure Tank.

Figure 27 Sealed Air Diaphragm Pressure Tank



Dugout water has little dissolved gas and can absorb the air in a plain galvanized steel tank. When most of the air is gone from the tank, it said to be waterlogged. This is like not having a pressure tank and causes premature wear of the pump motor. If a tank has no bladder or diaphragm, waterlogging can be avoided with regular addition of air to the tank. An air volume control can be added to jet pumps to add air to less expensive steel or floating wafer tanks.

The size of the pressure tank is also important. Select a pressure tank that has at least one gallon of drawdown between low and high pressure, for each gallon per minute (**gpm**) of pump capacity. For example, a ten gpm pump requires a pressure tank with ten gallons of drawdown.

Water Distribution System

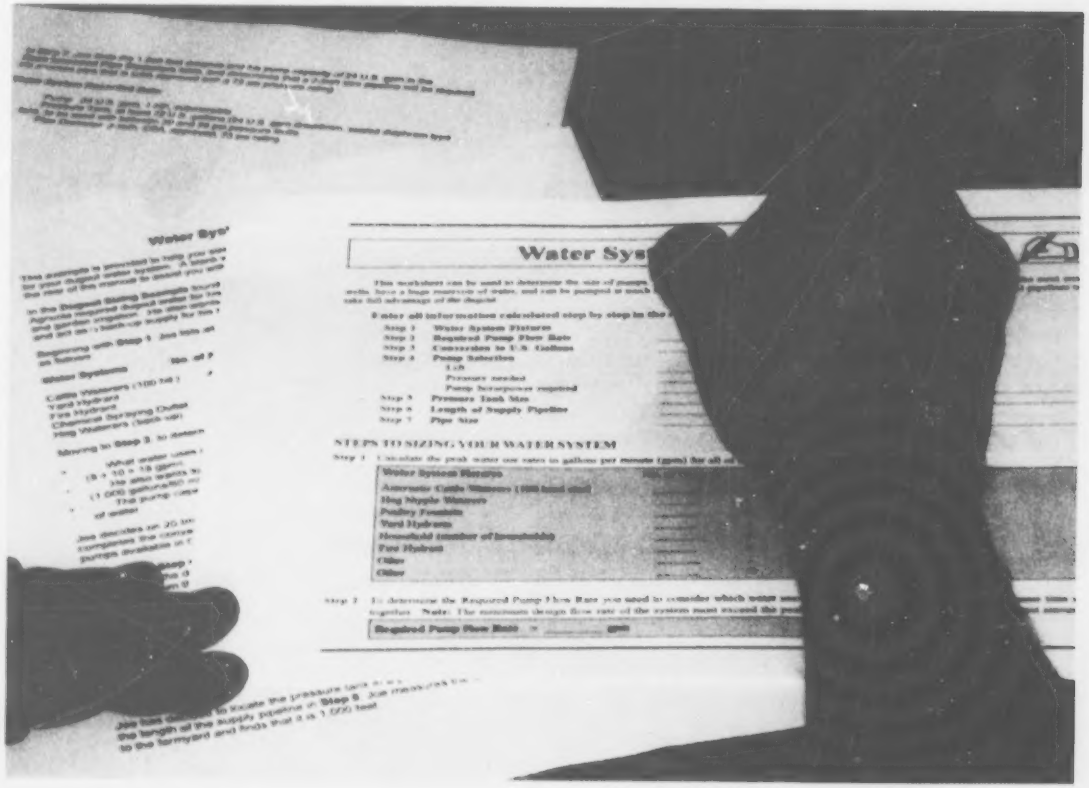
The water distribution line should be sized to effectively supply the required amounts of water and pressure throughout the system. As a rule of thumb, try to maintain no more than a five pound per square inch (**psi**) pressure loss due to friction, throughout the system.

For dugout applications generally 75 – 100 psi, CSA approved, polyethylene pipe is suitable for underground burial and general use in the water distribution system. Polyethylene pipe comes in low, medium, and high density. Low-density pipe is recommended because it is more resistant to damage, more flexible, and easier to join.

For pipe connections, it is best to use fittings that will not corrode from the water or contact with corrosive soil in an underground trench. Nylon, plastic, or brass fittings are recommended. Use 100 percent stainless steel clamps for all connections and double clamp underground connections.

The Figure 28 Water Sizing Example continues the example of the Joe Agricola farm to illustrate pump, pressure tank, and water pipe sizing for farm dugout, water distribution systems. Carefully work through the complete example contained in the pocket at the front of the manual. Blank worksheets for sizing the components of your water distribution system are contained in the pocket at the rear of the manual.

Figure 28 Water System Sizing Example



Dugout Aeration Systems

As previously outlined in the Understanding Prairie Dugouts Module, Biology of a Dugout section, an important part of maintaining water quality is ensuring that the level of dissolved oxygen in the water stays high all year round.

Under natural conditions in a dugout, oxygen exchange with the environment is not sufficient. In summer, a layer of warm water forms on the surface and floats on a layer of deeper, cooler water. The layer of cold water, having no contact with the atmosphere, becomes depleted of oxygen. Under low-oxygen conditions, plant nutrients, metals, and swamp gases are released from the dugout sediments and held by the cold water layer.

In fall, air temperature and the surface waters of the dugout cool rapidly. When the surface reaches the temperature of the cooler, bottom layer, the dugout 'turns over'. This means that the water in the dugout is no longer stratified and wind mixing of all the dugout water occurs. Nutrients and unwanted compounds become evenly distributed throughout the water.

During winter, ice cover prevents the transfer of oxygen from the atmosphere to the water. When oxygen is depleted, microbial activity in the sediments again begins to release unwanted compounds. One of these compounds, hydrogen sulfide, produces the rotten-egg smell that often develops in small water bodies in late winter.

The ice melts in spring, the surface warms, and the water mixes completely distributing the unwanted compounds throughout the water. Dissolved nutrients become readily available to plants and algae near the surface. As the air temperature increases, the cycle begins again.

In order to prevent this cycle of low-oxygen conditions from developing, supplementary aeration is required. This adds oxygen to the water and ensures complete mixing of the water so that contact with the atmosphere is maximized. Research has shown that dugouts should be aerated 24 hours per day, year round.

Types of Aeration Systems

Many types of aeration systems have been tried over the years including electrical, wind-powered, and solar-powered systems. Where possible, electrical systems are always preferred, but for remote locations, other power sources are required. All systems have advantages and disadvantages.

Wind-powered systems can be effective in low-sunlight winter conditions but only in areas where winds are relatively constant. Solar systems are very portable and work best in hot sunny conditions coinciding well with peak demand for water. Producers should try to find options that suit their operations and their geographic area.

Some floating systems are available but research indicates that these systems are not very practical or effective for prairie dugouts.

Components of an Aeration System

There are four components to an aeration system:

- power supply
- air compressor
- aeration line
- diffuser.

Power Supply

As with pumping systems, aeration can be powered by electricity, solar power, or wind. For dugouts stocked with fish, use an electrical type compressor, as it will provide a continuous supply of dissolved oxygen. This is crucial for fish survival in a dugout. Windmill type systems may not pump sufficient dissolved oxygen for fish survival during low wind conditions at night or during hot calm periods in summer.

Air Compressors

Bank-mounted windmills use a diaphragm-type pump that pushes air into an aeration hose that extends to the bottom of the dugout. Windmills are suitable for areas with good wind conditions and for remote sites where electrical power is too costly to install. However, they perform poorly on sites where winds are obstructed by hills or trees, water is deep (over 20 feet), or there are high concentrations of organic matter in the water.

The most common types of electrical compressors are the oil-less diaphragms or piston pumps. These compressors are quiet, relatively inexpensive to purchase and operate, and require little maintenance. When choosing a pump, make sure it is rated for continuous use. As a rule, a diaphragm-type compressor that pumps approximately one cubic foot per minute (**cfm**), for every million gallons of dugout water is adequate. For best results, locate the compressor in a heated building or enclosed box to protect the motor, diaphragm, and electrical supply.

Aeration Lines

Aeration lines convey air from the pump to the dugout. For new dugouts, the aeration line should be buried with the water intake line. This will prevent damage from frost, ultraviolet light, ice, and animals.

Diffusers

A diffuser is a device to release air into the water. Research has shown that the type of diffuser is very important. Diffusers that create fine to medium-sized bubbles are more efficient at circulating and aerating water than open-ended hoses that produce large bubbles. An open-ended hose requires three times the volume of air to saturate water with dissolved oxygen compared to an air stone or perforated hose. Proper location of the diffuser maintains oxygen levels from top to bottom, as shown in Figure 29 Aeratopm System. Recommended types of diffusers are:

- airstone diffuser, Figure 30
- lnear, fine bubble diffuser, Figure 31
- membrane diffuser, Figure 32.

Figure 29 Aeration System

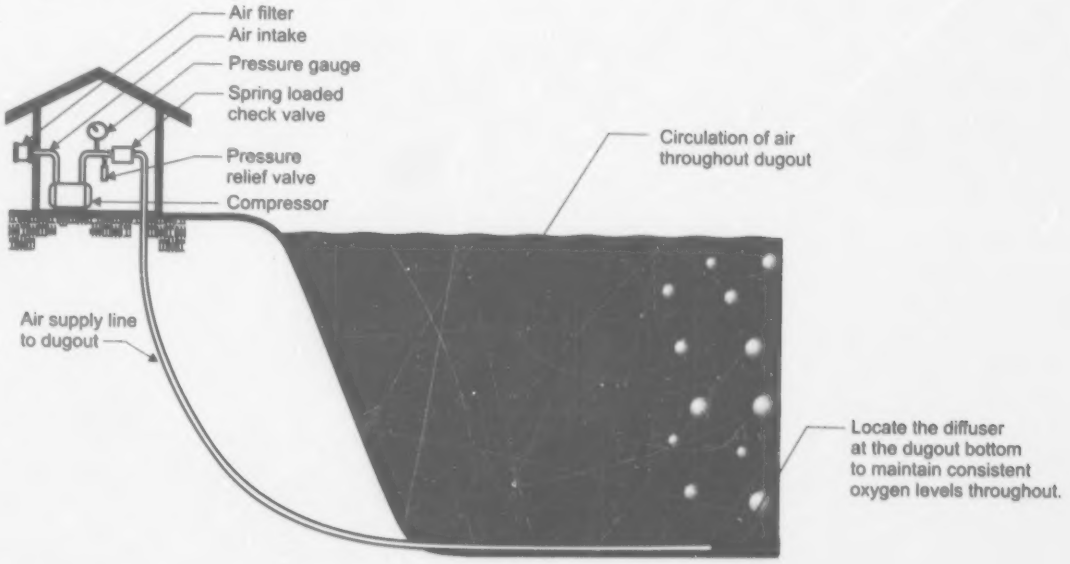


Figure 30
Airstone Diffuser

Figure 31
Linear Diffuser

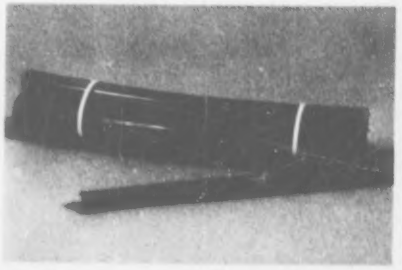
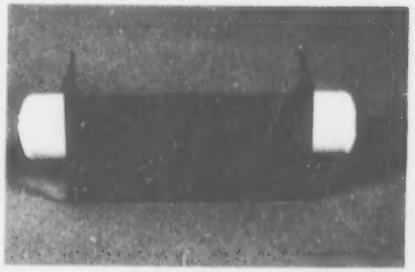


Figure 32
Membrane Diffuser



Safety

During winter, dugout aeration systems can result in open or weak areas in the dugout ice. These conditions can be very dangerous for young children, pets, and people snowmobiling at night. It is essential to educate your children about these hazards and post the area with highly visible warning signs and fluorescent snow fence around open water areas.

Pasture Water Systems for Livestock

Today, livestock producers want to provide a safe, reliable supply of good quality water for their livestock. They also want to better utilize their pasture dugouts. Direct watering of livestock from dugouts causes a number of environmental, herd health, and pasture utilization problems.

Problems with Direct Watering

There is enough dissolved phosphorus in the manure from one cow in one day to cause an algae bloom in 265,000 gallons (over 1,000,000 liters) of water.

The amount of oxygen needed to decompose the manure from one cow for one day will deplete all the dissolved oxygen in 8,000 gallons (over 30,000 liters) of water.

Direct access watering has a negative effect on water quality, herd health, and the lifespan of the farm dugout:

- Fecal pathogens are directly added to the water allowing for rapid spread throughout the herd. Problems may also arise due to pathogens causing footrot.
- Nutrient loading from excrement will lead to proliferation of algae populations and in some cases the production of toxins from cyanobacteria.
- Oxygen depletion results from the biological breakdown of excrement.
- Destruction of side-slopes from hoof action speeds sedimentation and shortens the life of a dugout.
- Cattle are sensitive to taste and odour in water supplies, and may limit their intake of less palatable water, possibly leading to reduced feed conversion and productivity.

Options to Direct Watering

Some of the most common livestock watering alternatives involve complete exclusion of animals from the water source:

- water hauling
- gravity-fed reservoirs
- pumped gravity flow reservoirs
- animal-operated pasture pumps
- pipelines from nearby water sources
- gas powered pumping and generator systems
- solar-powered pumping systems
- wind-powered pumping systems
- flowing water driven pumps including sling pumps, paddle pumps, and hydraulic ram pumps
- air compressor pumps.

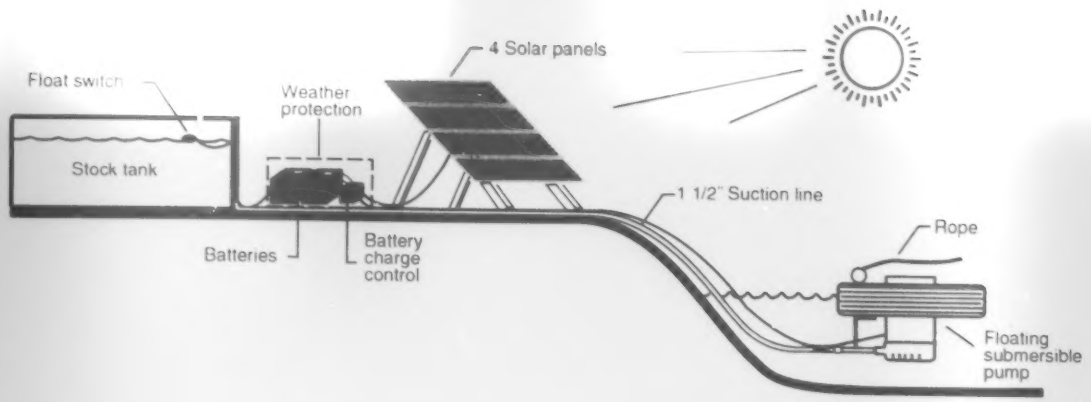
Many producers are also looking at winterizing their pasture water systems so that the pasture season can be extended and winter feeding done on pasture.

Remote Watering Equipment

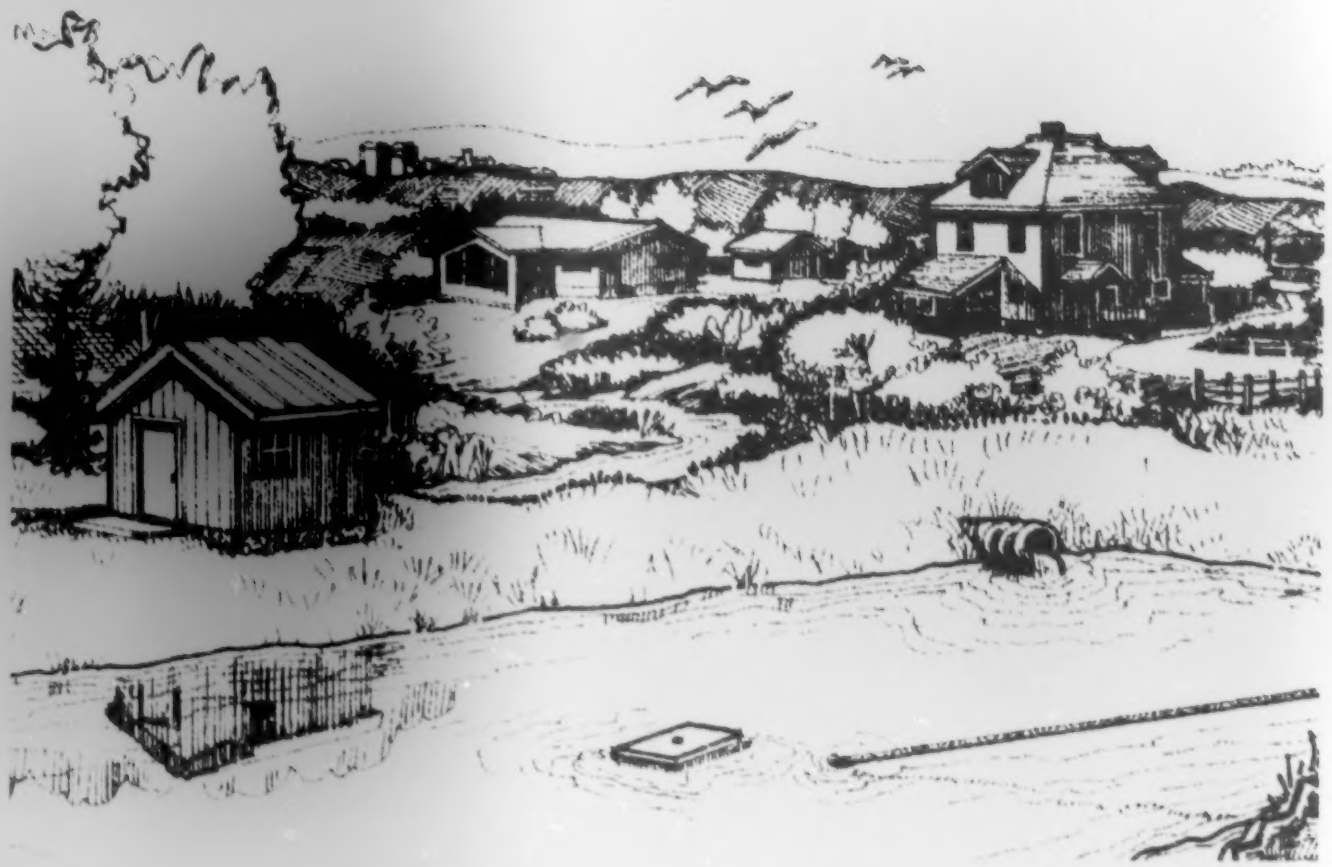
Essentially, a watering system requires a water source, a pump, storage of either water or power, and a watering device. Today there is a variety of livestock watering methods available to suit any type of pasture and location. The power options to move water to livestock include solar, wind, fuel, stream flow, main line electricity, and gravity flow. Selecting the most appropriate one can be a challenge. Establish a list of priorities and try to use some of the natural advantages of the site and equipment. Figure 33 illustrates a solar powered watering system.

An effective and well-planned pasture water system is a very important part of all livestock grazing plans. Plan for remote watering of livestock, at the same time as you plan for dugout construction and operation.

Figure 33 — ing System



Water Quality for Domestic and Drinking Water Supplies



Domestic and drinking water supplies have higher quality requirements than most other uses. Water that appears to be acceptable based on visual appearance, taste, odour, and colour may contain contaminants that affect human health. Risks can be chemical or microbiological. It should be remembered that water that has been successfully treated for human consumption might become re-contaminated and present real health risks. Re-contamination sometimes occurs in the distribution system.

On the other hand, water that is otherwise harmless may have such objectionable appearance, taste, and odour that it is unacceptable for household use.

Health Risks and Water Quality

On first appearance, water would appear to be a relatively simple liquid. It is, however, a powerful solvent that is capable of containing a very complex mixture of chemical substances. Water also provides a suitable medium in which a diverse range of microbiological organisms can exist. The presence of various chemical constituents and microscopic organisms in water may impact upon human health.

Microbiological Factors

There are three major groups of microbiological organisms that cause waterborne diseases:

- bacteria
- protozoa
- viruses.

Examples of each of these three groups of pathogenic organisms are given on page 114, Table 1, Appendix 2 Water Quality Guide, along with the symptoms of the resulting disease. It should be noted that all of the symptoms listed for a particular disease are not always observed. It should also be noted that this list is not exhaustive but contains examples of microscopic organisms that have been linked with waterborne diseases in the past.

In many cases, the association of a disease outbreak with exposure to contaminated water is not recognized. Many of the symptoms that are exhibited in some of these diseases are attributed to other factors such as the "flu" or food poisoning. As such, many cases related to waterborne disease are

never reported to health officials and therefore available statistical data are understated. The number of people contracting diseases from the consumption of contaminated drinking water is conservatively estimated to be between 900,000 and 3,000,000 each year in the United States.

In Canada, notifiable disease statistics are the responsibility of each province and considerable variation exists in the manner and completeness with which this information is collected. Consequently, the number of individuals affected by waterborne diseases is not known in Canada. If one assumes a similar rate of occurrence for waterborne diseases in Canada, between 90,000 and 300,000 Canadians may be affected annually by water contaminated with microbiological organisms.

In many cases where disease outbreaks have been linked to drinking water, the cause is never determined. In the U.S. from 1991 to 1998, the identity of the agent causing waterborne disease outbreaks was not determined in 40% of these cases.

Bacteria

Most bacteria found in water do not cause diseases in humans. Types of bacteria that do cause disease are found in the intestinal tract of warm-blooded mammals, including humans. These bacteria are excreted in waste matter and may be carried into water supplies.

Seepage from septic tanks and sewage lagoons, plus runoff from livestock feedlots, pastures, and cropland to which manure has been applied may contain bacterial contaminants. Similarly, fecal matter may also be introduced from rodents, birds, and other wildlife. Surface water supplies are therefore highly susceptible to bacterial contamination.

Once bacteria have entered a water supply, they may continue to reproduce, thereby maintaining or even increasing the degree of contamination. Surface water supplies that are largely immobile, like dugouts, provide an excellent breeding ground for bacteria.

Floodwater usually contains high levels of bacteria.

Protozoa

Protozoa are a group of microscopic parasites that are frequently present in surface waters. Some protozoa, notably giardia and cryptosporidia, exist in the form of cysts. The protective covering of the cyst permits the parasite to survive harsh environmental conditions. The cyst also protects the parasite against disinfectants such as chlorine. Once ingested, the parasite germinates and reproduces. Encysted parasites may subsequently be evacuated from the animal or human host through the feces.

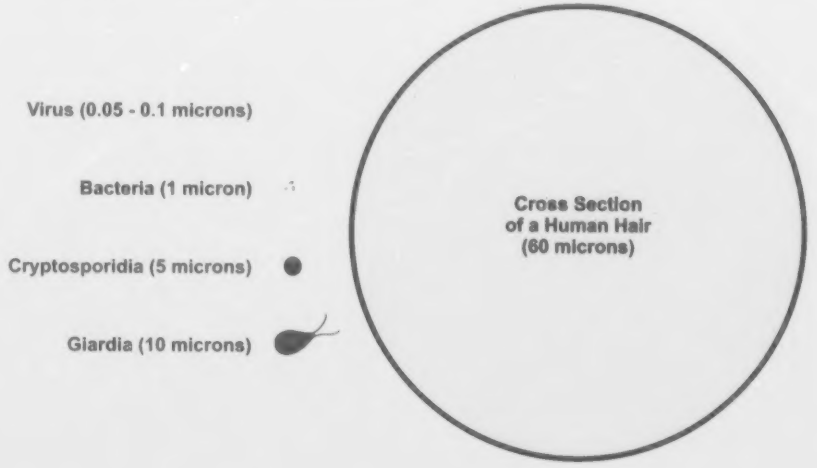
Cryptosporidia and giardia have been suggested as the causative agent in approximately 60% of reported waterborne disease outbreaks in the U.S. between 1991 to 1998. Giardia are found in feces from humans, beavers, muskrats, and dogs. Cryptosporidia have been found mainly in fecal matter from cattle, sheep, and pigs. However, they have also been detected in the feces of humans and other mammals. Contamination of water supplies occurs when fecal matter containing the parasites is deposited or washed into the water.

Viruses

Relatively little is known regarding the incidence of diseases resulting from waterborne viruses. However, a number of different waterborne viral agents have been found in contaminated water supplies and linked to disease including hepatitis A, rotavirus, Norwalk agent, over 30 types of adenoviruses, and over 70 types of enteroviruses.

Figure 34 Relative Sizes of Pathogenic Organisms illustrates why pathogenic organisms are not visible to the human eye.

Figure 34 Relative Sizes of Pathogenic Organisms



Chemical Factors

There are a number of chemicals that can pose a human health risk. In some cases, these materials are naturally present in water through weathering and erosion. In other cases, human activities result in the introduction of these chemicals into water.

Chemicals that potentially have an adverse effect upon human health include naturally occurring minerals, metals, and toxins as well as a variety of synthetic, organic chemicals including many different types of pesticides. A list of the various chemicals, their source, and their adverse health effects are listed in Appendix 2, Water Quality Guide, in Table 2, Chemicals and Their Associated Risk to Human Health, page 115.

If you suspect that your water contains elevated levels of naturally occurring chemicals, or if you believe that your water has become contaminated, specific tests may be performed in a laboratory. There are numerous laboratories with a diverse range of analytical testing capabilities located in each province. Contact your regional health authority to obtain contact information for water-testing laboratories.

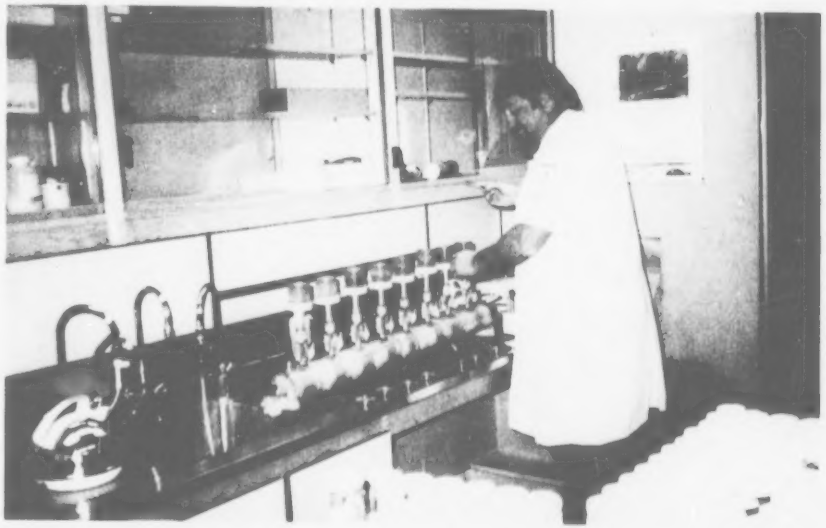
Aesthetics and Water Quality

Numerous chemical compounds and microbiological species affect the aesthetic quality of water. Certain species impart an objectionable taste or odour to water while others may cause staining or leave behind a residue or solid precipitate. These chemical agents and microbiological species are generally regarded as nuisances that typically do not pose a risk to human health. The most commonly encountered nuisance water problems are summarized in Appendix 2, Water Quality Guide, Table 3, Chemical Agents and Microbiological Species Affecting Aesthetic Quality of Water, page 116. The source of the nuisance impurities and organisms are listed along with the symptoms typically observed as a result of their presence in water. The presence of these impurities and organisms can be confirmed by laboratory tests. Once their presence has been determined, appropriate steps may be taken to eliminate or minimize the associated problems.

Standard Testing of Drinking Water

Regular testing of water is necessary to monitor the effectiveness of a treatment system. From the point of view of health and safety, microbiological testing of water is of prime importance.

Figure 35 Saskatchewan Health Provincial Lab



Testing for Coliforms

Coliform bacteria are commonly found in the environment. While most of these organisms are not harmful, their presence is an indicator that other harmful or pathogenic micro-organisms may be present. An assumption is made that if coliform bacteria are absent, then pathogenic bacteria are also probably absent. Similarly, if coliform bacteria are present, it is assumed that pathogenic organisms are also present. Therefore, in public water supplies, the presence of coliform bacteria indicates a problem with the water treatment system. It could also indicate inadequate disinfection within the distribution system, or a break in the water pipes. Similarly, the presence of coliform bacteria in private water supplies may be indicative of a contaminated water source or a faulty treatment system.

Most water-testing laboratories in Canada, and for that matter many other countries, perform what is known as the analysis for total coliforms. This test is used to indicate the presence of a diverse group of bacterial organisms. In some test procedures, an estimation of the quantity of bacteria present is determined, and listed as the number of colony forming units per milliliter of water tested. However, other tests simply indicate the presence or absence of coliform bacteria.

If a water sample is found to contain coliform bacteria, the next step is to determine whether any of these bacteria are due to fecal contamination. This is generally done by testing the water for fecal coliforms or specifically for *E. coli*. The presence of fecal coliforms or *E. coli* indicates that the water is contaminated by either human or animal waste. Micro-organisms from these wastes can cause diseases.

It must be emphasized that if a water sample is positive for total coliforms but does not contain fecal coliforms or *E. coli*, the sanitary quality of this water is still considered unacceptable. If coliform bacteria can survive, there is the potential for pathogenic micro-organisms to exist in the future.

Suspended particles or cloudiness in water is a potential indicator of water contamination and may indicate problems with treatment processes. Highly turbid water also reduces the efficiency of disinfection processes such as chlorination and UV treatment. The amount of suspended particles or cloudiness may be measured as a turbidity test. Municipal and community water supplies typically monitor turbidity on a routine or continuing basis.

In 1989, the Mistahia Health Unit, formerly South Peace Health Unit, located in Grande Prairie, Alberta conducted a survey of bacteria levels found in local farm dugouts. Health Unit staff reviewed the results of bacteriological analysis conducted on raw (untreated) dugout water samples from the 1960s to 1989.

Bacteria Found	Samples Containing Bacteria
Total coliform	31.5%
Fecal coliform	23.7%
Total bacteria population (>500)	1.2%
Confluent growth (unidentified bacteria)	1.7%
Meets Canadian Drinking Water Guidelines (1989)	41.9%
Total water samples tested	**578**

Note: Information provided by Elmer Spilchen, Public Health Inspector, Grande Prairie, Alberta.

Water testing is done for indicator bacteria rather than a number of individual species.

The survey results indicate that dugouts are at risk of contamination with bacteria, and confirm the need for effective treatment of dugout water to be used for household purposes.

Pitfalls of Standard Water Testing Techniques

If a treated municipal drinking water supply is found free of coliform bacteria, it is generally assumed that the water treatment process is working adequately and that the distribution system is functioning properly. While most pathogenic bacteria and viruses are destroyed by disinfection, some organisms such as cryptosporidia and giardia may not be inactivated. Therefore, an acceptable result for coliform bacteria does not guarantee that all pathogenic organisms have been eliminated. Furthermore, an acceptable result for coliform bacteria on an untreated water supply such as a private well or dugout does not indicate anything regarding the presence or absence of protozoa or viruses.

Non-routine Testing of Drinking Water

While there are numerous laboratories that have the capability to test for coliform bacteria, total and fecal, as well as *E. coli*, relatively few have the capability to test for specific pathogens such as cryptosporidia, giardia, and various viruses. Many environment and health officials do not recommend routine monitoring of drinking water supplies for cryptosporidia and giardia due to the complex and expensive testing methods and the widespread existence of these protozoans in surface water. Instead of monitoring for protozoans, many agencies have preferred to focus on ensuring that adequate treatment procedures are in place for public and private water supplies and that best management practices are observed in the watershed.

Very few laboratories have the capability to test water routinely for viruses. This is mainly due to the lack of established testing procedures for many viral organisms. A second factor is that most laboratories perform microbiological testing on a very large number of samples. Testing all of these samples for even a small number of viruses would be practically impossible. This type of testing is normally only performed on the drinking water supplies of larger municipalities.

General Testing Recommendations

It is impossible to test a water sample for all known pathogens. It is also very expensive to test for a large number of different pathogens. Many health agencies have designated total coliforms as a standard indicator test to determine the bacteriological safety of drinking water. Test drinking water derived from a privately operated source such as a well or dugout at least twice a year for bacterial safety. More frequent testing may be necessary if contamination is suspected or unexplained illness occurs. If continuing illness is observed, discontinue use of the water until a sample has been tested.

Water Treatment for Domestic Water Supplies

Water Treatment Systems

Water treatment is essential for all dugout water supplies used for household/drinking purposes.

Water treatment involves a series of separate treatment processes in a standard sequence to produce a safe and aesthetically acceptable product. This sequence of treatment processes improves the quality of the water with each step, providing a multi-barrier, water treatment system. For surface water supplies, treatment must include steps to remove particulate and organic matter, followed by disinfection. Water treatment equipment can be expensive and always requires good maintenance practices to operate effectively over the long-term.

Surface runoff is usually high in particulate matter and plant nutrients. Algae and weed growth can be significant, particularly during the summer months, and dugouts generally have high levels of organic matter. While disinfection is an essential part of the water treatment process, high organic carbon levels can react with the disinfectant, producing potentially harmful by-products. The reduction of organic matter prior to disinfection is therefore an important step in the treatment process to produce biologically and chemically safe water.

Traditionally for domestic use, dugout water treatment has consisted of either no treatment at all, or a combination of chlorination, rapid sand filtration, and/or granular activated carbon filtration. These types of treatments, by themselves, have not been successful at producing a high water quality product over the long-term. Water produced from this type of treatment system should only be considered utility water and should not be consumed. While these processes can be effective to some extent, more effective pre-treatment is essential.

If you are not going to adequately treat water, then haul good quality water for household purposes.

*Point-of-entry (**POE**) systems treat all the water as it enters the house.*

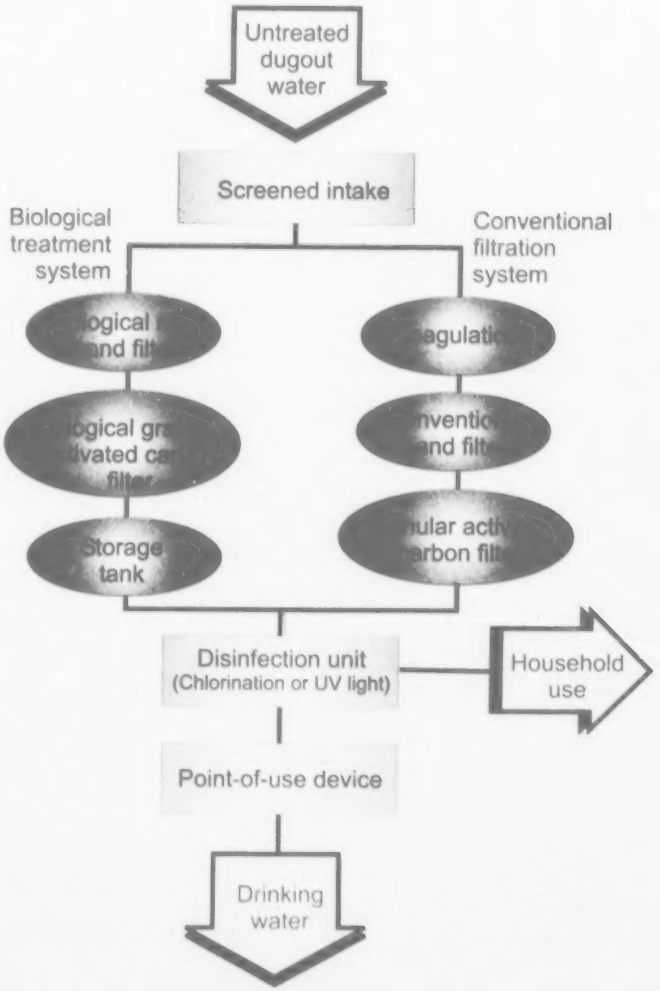
*Point-of-use (**POU**) devices treat small amounts of water at the tap.*

Figure 36 Surface Water Treatment Steps shows a schematic of two effective systems for treatment of dugout water as it enters the house. These systems are called 'point-of-entry' (**POE**) treatment systems. The first system includes chemical coagulation, filtration, and disinfection. The second system includes slow sand and biological activated carbon filtration followed by disinfection. In both cases, a final barrier such as a reverse osmosis (**RO**) membrane or distiller for drinking water, cooking water and water for brushing teeth is added. This final barrier is called a "point-of-use" (**POU**) water treatment device. This type of treatment following point-of-entry treatment is referred to as 'polishing'. Polishing devices are designed for use on high quality treated water and are not capable of treating raw dugout water.

An effective in-house treatment system should be represented by one of the configurations in Figure 36. Other technologies, such as micro filtration, may be used to replace some of the processes identified in Figure 36 if they are properly designed and operated.

The treatment processes described can effectively treat most dugout water. Effective systems are designed to treat specific water problems. Therefore, dugout water should be tested before designing the system. Water problems that are not typical of dugouts may require system modifications.

Figure 36 Surface Water Treatment Steps



Steps in Water Treatment

The recommended systems, Figure 36, consist of several consecutive steps. As previously discussed in Module 3 – Planning, the first step in a multi-barrier water treatment system is protection of the source water.

Screened Intake

A screened intake in the dugout is recommended as a pre-treatment to sieve out larger particles including algae, as well as reduce high turbidity.

Coagulation

Coagulation is a chemical process that can reduce turbidity, dissolved organic compounds, and colour. The chemicals most often used for coagulation are aluminum sulphate, ferric chloride, ferric sulphate, and polyaluminum chloride.

The coagulant causes small particles to join to form larger particles. During mixing, more particles combine to form even larger particles called **floc**. The floc is visible to the naked eye and can be removed from the water through sedimentation or direct filtration.

Coagulation can be done in dugouts or coagulation cells, or by using in-house coagulation systems. The two most common methods of coagulation for rural use are:

- constructing a small lined dugout or coagulation cell to treat a six to twelve month supply of household water
- utilizing a commercial in-house coagulation system for continuous treatment of household water.

*For more information about coagulation, contact your nearest **PFRA** district office.*

Coagulant chemicals must be dosed and mixed properly to achieve maximum benefits. On-farm coagulation has been experimentally successful, using simple treatment techniques for rural water supplies. Simple predictive tests have been developed for use on-site to determine the required dose rate.

Conventional Filtration

Conventional filtration is also known as rapid filtration, to distinguish it from slow sand or biological filtration. Figure 37 shows continuous coagulation treatment followed by conventional filtration. Filtration is an important step in the treatment sequence to remove particles from water. Types of filter media that can be used include sand, dual media, multi-media, and granular activated carbon. Pressure sand filters and granular activated carbon filters are commonly used in domestic systems. Granular activated carbon filters can be used as a final step to remove taste and odour. In all cases, filters require backwashing to maintain performance. Backwashing is accomplished by reversing the flow of the water and lifting the media bed. Solids clogging the filter are dislodged and flushed out with the backwash water, which is discarded.

Biological Filtration

As an alternative to conventional filtration, biological filtration, as shown in Figure 38, can be a simple but effective treatment for small water supplies. Slow sand filtration, followed by disinfection, represents one of the earliest systems developed for the treatment of surface water supplies. While these filters are commonly employed in many European treatment systems, they are not heavily used in North America.

Biological filtration makes use of naturally occurring microorganisms to purify water. By providing the right environment, certain populations of microorganisms can be encouraged to grow in the filter. The process is simple. Water is percolated slowly through a filter bed and into a storage tank. A storage tank is required for the treated water because filtration is slow. A constant supply of air must be introduced to the filter and the flow of water must be continuous to ensure survival of the microbial colonies. As with the rapid sand filter, backwashing is required to maintain the operation of the filter. Some biological systems are ideally suited to treat surface water problems, such as dissolved organic carbon, turbidity, colour, taste, and odour. One system that has been successful in the treatment of surface water consists of a gravity-fed, slow sand filter, followed by a biological, granular, activated carbon filter and a storage tank.

This system offers an effective alternative to more conventional treatment systems and produces high quality, household water. With further treatment, water from these systems can be made safe for drinking. Although no chemicals or bacteria have to be added to these systems, regular backwashing with a mixture of air and water in a 'reverse' up-flow through each filter is a necessary maintenance procedure.

Figure 37 Coagulation and Conventional Filtration System

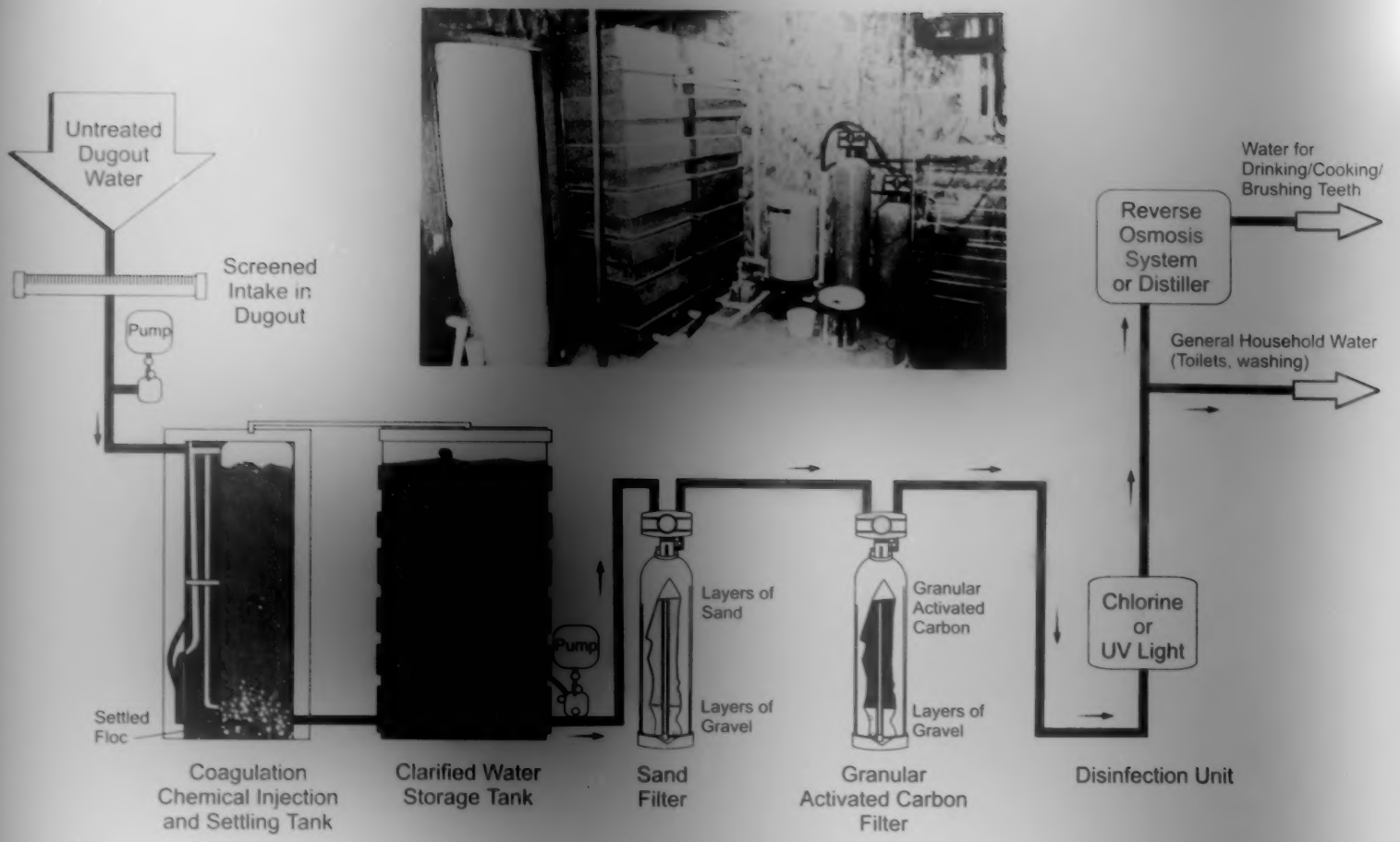
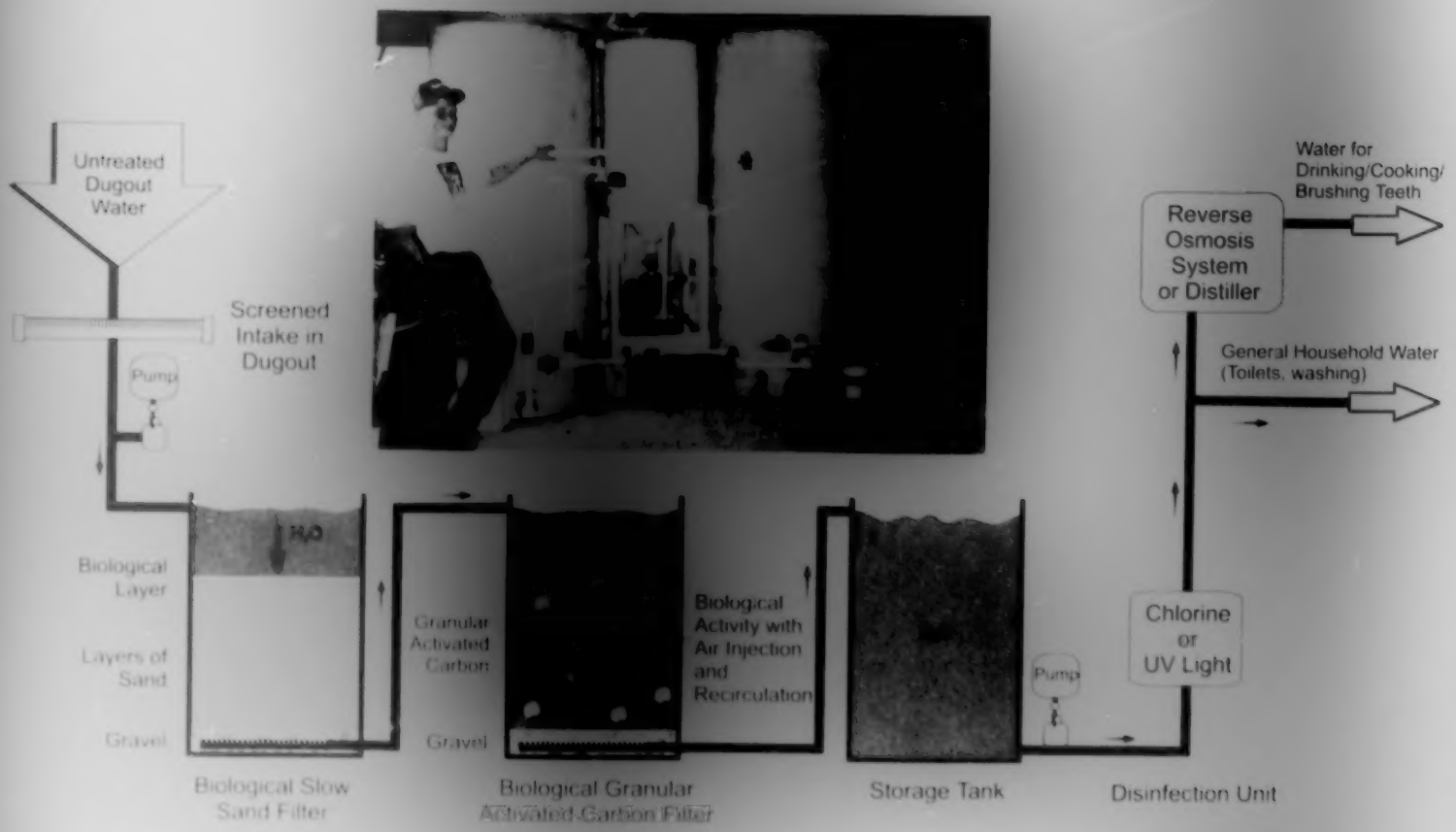


Figure 38 Biological Filtration System



Disinfection

Disinfection is an essential step in the treatment of dugout water for domestic use. The purpose of disinfection is to reduce populations of pathogenic microorganisms to prevent the transmission of water borne diseases. This is different from sterilization, which completely destroys organisms. Common disinfectants include chlorine, chloramines, and ultraviolet (**UV**) light disinfection. It is important that the water has been successfully filtered prior to the disinfection step.

Organic material and mineral particles can shield microorganisms from the disinfectant, resulting in water that may be unsafe even after treatment. In addition, if chlorine is used as the disinfectant, and organic matter has not been reduced to low levels, potentially harmful chlorination by-products may form.

Contact time, pH, water temperature, organic concentration, and chlorine dose influence the effectiveness of chlorine disinfection.

Many rural residents prefer UV light disinfection, as it imparts no smell, taste, or odour to the water. UV light disinfection does not require chemical feed pumps and mixing tanks; however, it does not leave a disinfectant residual like chlorine for protection throughout the household distribution system. Wavelength, exposure time, water temperature, intensity of the light, and the presence of turbidity affect the effectiveness of UV light disinfection.

Polishing Treatment for Drinking Water

While it is recommended that the entire household water supply be disinfected to protect all water outlets in the home, a final barrier to supply safe drinking and cooking water is also recommended. This additional polishing step requires a distiller, or kitchen sink reverse osmosis unit. For additional detail on distillers and RO systems, see pages 78 – 80 in this module.

Maintenance of Treatment Systems

Operation and maintenance of in-house treatment systems is critical. If dugout owners are not prepared to invest the time and money required into treatment system maintenance, safe drinking water should be obtained elsewhere. Some treatment systems can be purchased with maintenance contracts to reduce the time and work associated with proper maintenance. A well-operated system will ensure that the water supply is safe and aesthetically pleasing. Regular monitoring of systems will give users confidence that the water they are using is safe. Maintenance should be tracked in a record book. If changes in quality are observed, corrective measures should be taken.

Conventional Pressure Sand or Multi-Media Filters

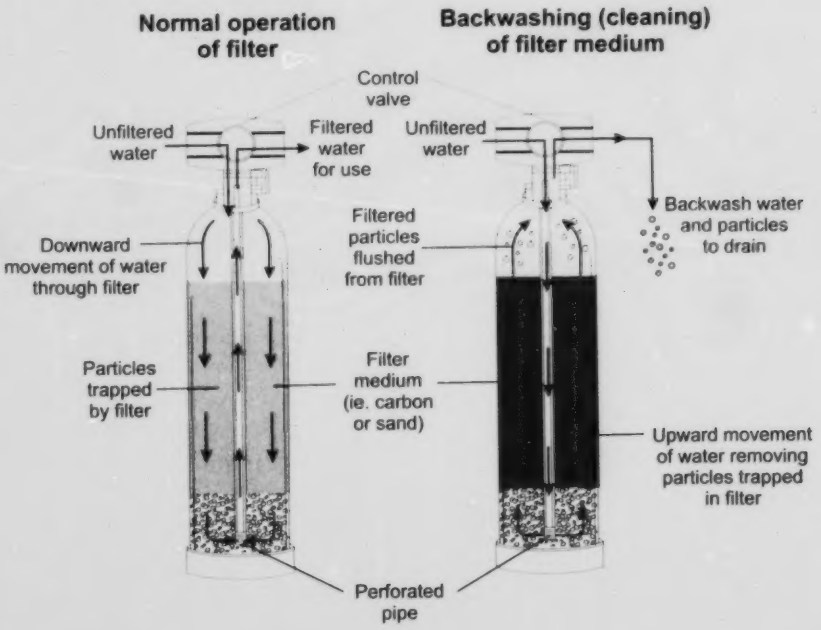
Pressure sand filters require regular backwashing as shown in Figure 39. The backwash cycle can be set to start automatically. Backwashing frequency will depend on how much loading is placed on the filter by the feed water. In summer, when particulate loading is high, backwashing may be required as frequently as once a day. In winter, backwashing may only be required once every three to seven days. If water is pre-treated with continuous coagulation before the filter, the requirements for backwashing may be increased as unsettled floc from the coagulation process may clog the filter.

Organic matter will accumulate and plug pressure sand filters over time. For this reason, a manual backwash should be done at least twice annually, once in spring after snowmelt and once in fall, just before freeze-up. A manual backwash involves turning on the filter in backwash mode, unplugging the timer, and running a large quantity of water through the filter. Clean filtered water is preferred for backwashing. However, if raw water is used in this process, the wastewater should look as clear as the raw water. The backwash water should be inspected every 5 minutes for clarity. The manual backwash should be repeated until the backwash water is clean. If a filter is very dirty, backwashing may have to be repeated. If organic slime build-up is a problem, the filter can also be shock-chlorinated after the manual backwash. Filter media rarely require replacement unless the coarse filter gravel is displaced during overly aggressive backwashing.

Biological Sand Filters

Biological gravity sand filters may be designed for two types of maintenance regimes. The first regime involves backwashing the filter once every two to four weeks. The second involves replacement of the top layer of sand with new sand. Each spring and fall, the sand filter may require several cycles of backwashing to remove any accumulated material.

Figure 39 Filter Backwashing



Conventional Pressure Carbon Filters

Pressure carbon filters also require regular backwashing. If a sand filter is operating efficiently, the pressure carbon filter will require backwashing once every 3 to 14 days. It is always important to follow manufacturer's recommendations and adjust the frequency of backwashing to the type of water being treated. Manually backwashing for a longer time than the automated backwash may be useful if particulate matter has overloaded the filter. This should be done any time overloading is suspected.

A significant problem associated with carbon filters is carbon exhaustion. This occurs when the carbon simply cannot adsorb any more taste and odour compounds or dissolved matter. Carbon exhaustion is identifiable by treated water that is coloured or has a bad odour. The adsorption capacity of activated carbon in a pressure carbon filter will not last forever. For dugout water supplies, carbon media should be replaced at least twice a year, once in fall and once in spring. Fall replacement, when organic matter has died off, provides better carbon filtration throughout the winter months. Spring carbon replacement, after spring runoff, provides for more effective filtration of water high in organic matter.

Granular activated carbon in the filters is only effective for 2 to 3 months. Carbon can be an excellent surface for unwanted microorganisms to grow on. Backwashing may not remove them and pre-treatment with chlorine will not prevent them from growing. Carbon must be replaced regularly to guarantee high quality water.

Biological Granular Activated Carbon Filters

Biological, granular activated carbon filters should be backwashed every 6 months. After the backwash, the filter should be drained of treated water until the water runs clear. Some fine carbon particles will wash through the system and should be discarded. Periodic shock chlorination is not required on biological carbon filters. If carbon media degrade, they require replacement. Long-term experiments on biological carbon filters have shown that the filters have performed well for seven years without any need for carbon replacement. The keys to successful biological carbon filtration are:

- ensuring that the system is sized properly
- providing a continuous air supply
- backwashing frequently.

Raw water should not be chlorinated before passing through the filter. Nor should it contain any compounds, such as copper, that may poison the organisms.

Chlorination Disinfection

Chlorine solutions must be batched to a mixing tank. The chlorine feed pump is then set to feed the chlorine solution into the filtered water. To ensure the water is safely disinfected, chlorine must be applied **after** filtration. Contact time must be 10 to 20 minutes and the dose must be large enough to ensure that the residual at the tap is at a suitable level.

The only way to know the concentration of chlorine at the tap is to test it. Test kits are cheap and easy to use. Testing must be done at least once a week and doses adjusted if necessary. A loss of chlorine residual at the tap may be due to the loss of prime at the chemical feed pump, or the failure of the treatment system. This type of monitoring is an excellent way to track the system's performance. Keep a logbook and record the results. Take any necessary corrective action if a problem is noticed. Properly managed and monitored, chlorination systems are the most effective way of ensuring that filtered water is safe for domestic use.

Ultraviolet Light Disinfection

Ultraviolet disinfection lamps occasionally become impaired by poor quality water. If the lamp becomes coated with organic material or mineral scale, disinfection will be incomplete. Lamp maintenance under these conditions is not practical, and it is therefore critical that UV is **not** used to treat hard water.

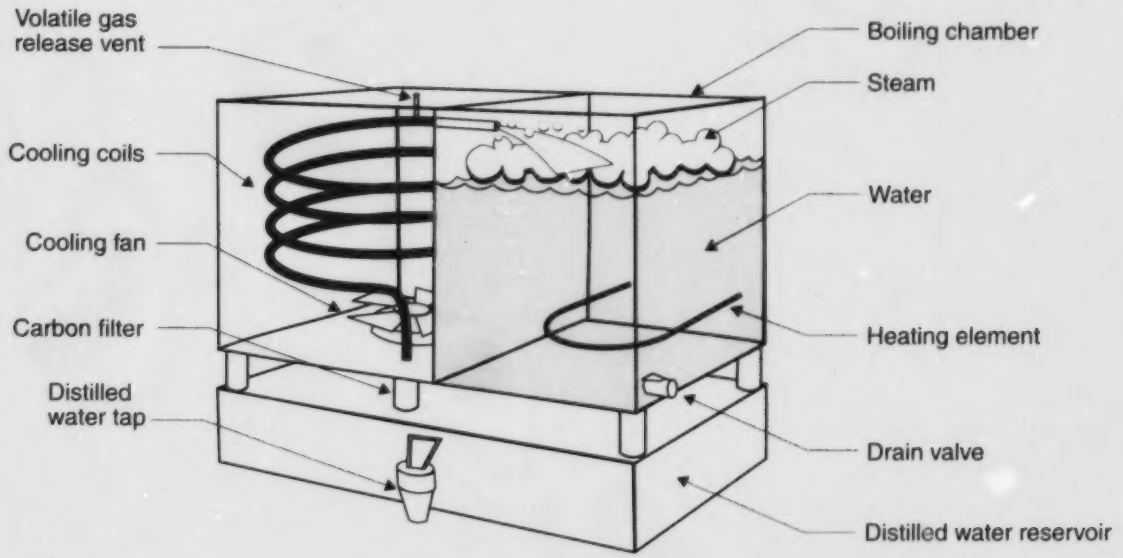
UV lamps must be routinely replaced.

UV bulbs must be routinely replaced in accordance with manufacturer's instructions or when so indicated by warning lights. There is no way of knowing if the lamp is disinfecting properly, other than to test the water at a laboratory for microbial contamination. There are concerns that UV performance can be critically impaired by electrical supply variations. A dedicated power supply to the lamp is recommended. Do not install lamps on circuits that have other high load demands. It is extremely important that the bulb be functioning properly and that units be equipped with indicator lights to serve as a reminder for bulb replacement.

Distillers

Distillers, as shown in Figure 40, require regular cleaning using compounds recommended by the manufacturer. Cleaning frequency will depend on the type of water being treated. Distillers remove chlorine, so when testing for chlorine residual, draw the sample ahead of the distiller.

Figure 40 Water Distiller



Reverse Osmosis Units

There are many types of reverse osmosis (RO) membrane units available. All are designed for use on very high quality feed water. It is common to incorporate a 5-micron filter, followed by a granular activated carbon filter, before the membrane as shown in Figure 41. A compressed carbon block filter cannot be used in place of granular activated carbon filter. Both the 5-micron and the granular carbon filters require replacement at least four times per year. If the canister housings of the filters are slimy, they can be shock chlorinated and scrubbed as a part of the maintenance regime.

RO membranes as shown in Figure 42 reject most of the dissolved solids in water. If a total dissolved solids (**TDS**) test shows more than 50 TDS, the membrane is not working satisfactorily. Some units have indicators to warn of this condition. The RO membrane requires replacement once every one to three years. Sealing rings and end caps are critical features of the membranes. If they are damaged or incorrectly installed, water will by-pass the membrane and remain untreated. Corrective action is required immediately. If an RO unit stops producing water, the filters or the membrane are likely plugged. Replacement is required.

Figure 41 RO Treatment Process

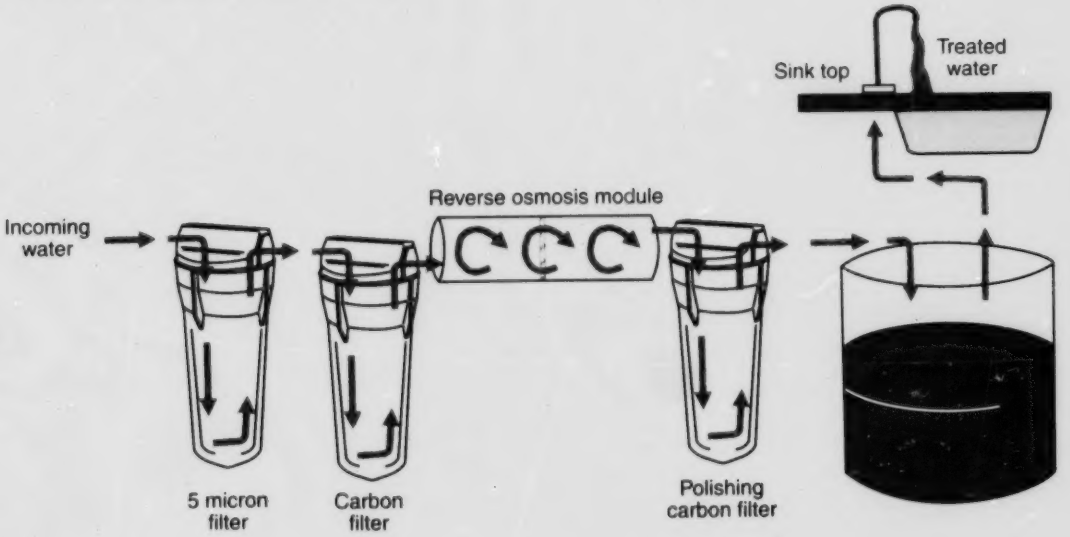
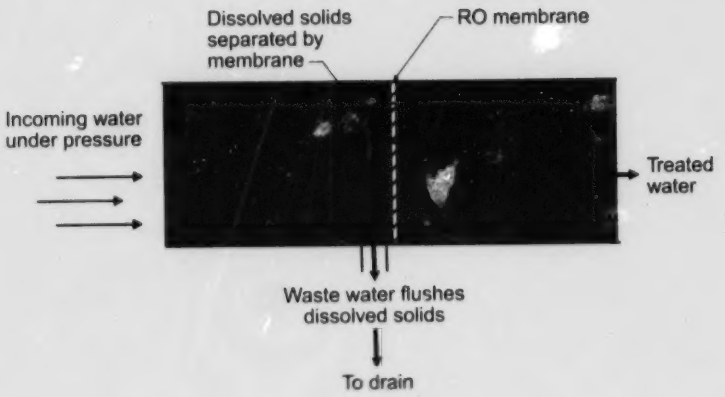


Figure 42 RO Membrane



Do not shock chlorinate RO membranes since they only tolerate low levels of chlorine. RO membranes remove chlorine, so when testing for chlorine residual, draw the sample ahead of the RO.

A granular carbon, polishing filter is often incorporated after the RO. This filter should be replaced at least four times per year. Granular carbon, polishing filters do not have to be discarded when replaced. They can be re-used once as the carbon filter in front of the RO.

Always follow manufacturer's recommendations for correct operation and maintenance procedures. The procedures must be suited to the specific treatment device.

Monitoring

Regular monitoring is the only way to determine how well a treatment system is performing. Keep a record of chlorine residuals, backwashing frequency adjustments, source water appearance, clarity, smell, and taste. Monitoring costs very little and increases confidence that the system is working well.

To judge the performance of a treatment system, test tap water for microbial safety at least twice per year. Critical times for water testing are:

- following spring runoff
- following any major runoff event
- mid-summer
- during maximum ice thickness.

Collect water in sterile bottles following the instructions of the lab performing the tests. Samples must be properly labeled and packaged, and delivered to the lab within 24 hours. Keep all results in a binder.

The following two Operation and Maintenance Schedule examples, Figures 43 and 44, show both the conventional treatment system, and biological treatment system. Carefully review the examples to see the type of information recorded. Blank schedules for your use are located in the pocket at the back of the manual.

Equipment Certification

In Canada, water treatment equipment for private systems is not required to meet any standards or regulations. Furthermore, there is no Canadian certification mechanism for the effectiveness of water quality treatment.

Figure 43 Conventional Water Treatment System Schedule

Operation and Maintenance Schedule

Conventional Water Treatment System Operation and Maintenance Log

N.B. Chlorine always tested at kitchen sink tap

Date	Coagulation	Sand Filter	Carbon Filter	Chlorinator	Distiller
Feb 28	*Little floc visible*	*Backwashing once/7 days*	*Backwashing once/7 days*	*Tot. Cl = 0.5 mg/L*	*Cleaned Unit*
March	*Not tested; on holidays*				
April 2	*Adjusted dose for spring water*	*Manual backwash for 30 minutes and shock chlorinated filter; backwashing once/4 days*	*Replace carbon media; backwashing once/6 days*	*Tot. Cl = 0.0 mg/L increased to 0.5 mg/L*	*Cleaned unit; replaced elements*
April 9	*Settled floc OK*	*Backwashing once/4 days*	*Backwashing once/6 days*	*Tot. Cl = 0.2 mg/L; new batch and re-set to 0.5 mg/L*	*Working OK*
April 16	*Floc seems to be thickening*	*Changed to once/3 days*	*Changed bacvkwashing to once/5 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 23	*More floc evident*	*Changed to once/2 days*	*Changed backwashing to once/4 days*	*Tot. Cl = 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
April 30	*Floc is similar to last week*	*Backwashing once/2 days*	*Backwashing once/4 days*	*Tot. Cl = 0.6 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 7	*Floc turning brownish*	*Backwashing once/2 days*	*Backwashing once/4 days*	*Tot. Cl = 1.0 mg/L Re-set to 0.5 mg/L*	*Working OK*
May 14	*Floc brownish, same denssity*	*Backwashing once/2 days*	*Backwashing once/4 days*	*Tot. Cl = 0.1 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 21	*Thick floc (algae and sediment from rain)*	*Re-set backwashing to once/day*	*Backwashing once/4 days*	*Tot. Cl= 0.3 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
May 28	*Floc is still thick*	*Backwash once/day*	*Changed backwashing to once/3 days*	*Tot. Cl = 0.2 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*
June 7	*Floc is thinner*	*Re-set backwashing to once/2 days*	*Re-set backwashing to once/4 days*	*Tot. Cl = 0.7 mg/L Re-set to 0.5 mg/L*	*Cleaned unit*

Figure 44 Biological Water Treatment System Schedule

Operation and Maintenance Schedule

Date	Slow Sand Filter	Biological Carbon Filter	Storage Tank	Ultraviolet Light	Reverse Osmosis
Feb. 28	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp is on*	*TDS is 350 mg/L (RO needs replacement)*
March	*On holidays; neighbours opened taps to flow 500 L of water weekly; air pumps OK*			*Removed lamps; stained!*	
April 2	*Two manual backwashes with air and water and shock chlorinated filter*	*Three manual backwashes with air and water, filtered water was dirty, drained until clean*	*Shock chlorinated the tank*	*Replace UV bulb and quartz sleeve*	*Replaced membrane and all filters (5 micron, both carbon filters); TDS is 50 mg/L*
April 9	*Air stone replaced; old air stone was plugged*	*Air stone was replaced*	*Air pump and air stone is OK*	*Farm power surge. UV on/off test performed to check UV, OK*	*TDS measured 45 mg/L*
April 16	*Air pump working*	*Air pump working*	*Air pump working*	*UV lamp OK*	*TDS measured 45 mg/L*
April 23	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV quartz sleeve cleaned*	*TDS measured 53 mg/L*
April 30	*Manual air and water backwash*	*Air pump OK*	*Air pump OK*	*Replaced UV ballast (damaged by power surge)*	*TDS measured 55 mg/L*
May 7	*Air pump OK*	*Air pump OK*	*Air pump OK*	*UV lamp OK*	*TDS measured 150 mg/L ?? calibrated meter, TDS 65 mg/L*
May 14	*Dirty water but filter working OK*	*Filter OK, air supply OK*	*Water still OK and air system working*	*UV lamp OK*	*TDS measured 57 mg/L*
May 21	*Filter starting to plug, so performed mini-backwash*	*Flow rate slowing down*	*Air system OK*	*UV on/off self-test performed*	*TDS measured 70 mg/L*
May 28	*Manual air and water backwash*	*Filter flow OK after sand backwashed*	*Air system OK*	*UV lamp indicator OK*	*TDS measured 60 mg/L*
June 7	*Air pump working*	*Air pump working, stone OK, circulation seems fine*	*Air system OK*	*UV quartz sleeve dirty; cleaned sleeve*	*Replaced plugged 5 micron filter TDS mesured 55 mg/L*

Although private treatment systems are not regulated in the United States, the National Sanitation Foundation International (NSF International) does certify small treatment devices if the manufacturer is willing to apply and pay for the third party evaluation. Try to find equipment that meets certification by NSF International to ensure that equipment performance has been validated against accepted standards. Be aware, however, that the test was probably not performed using water as challenging to treat as dugout water

Devices may also be registered with the United States Environmental Protection Agency (EPA). This registration means the equipment has been tested to ensure the device will not give off contaminants that may harm the consumer. The EPA does not test equipment performance.

Most importantly, work with a dependable water treatment company.

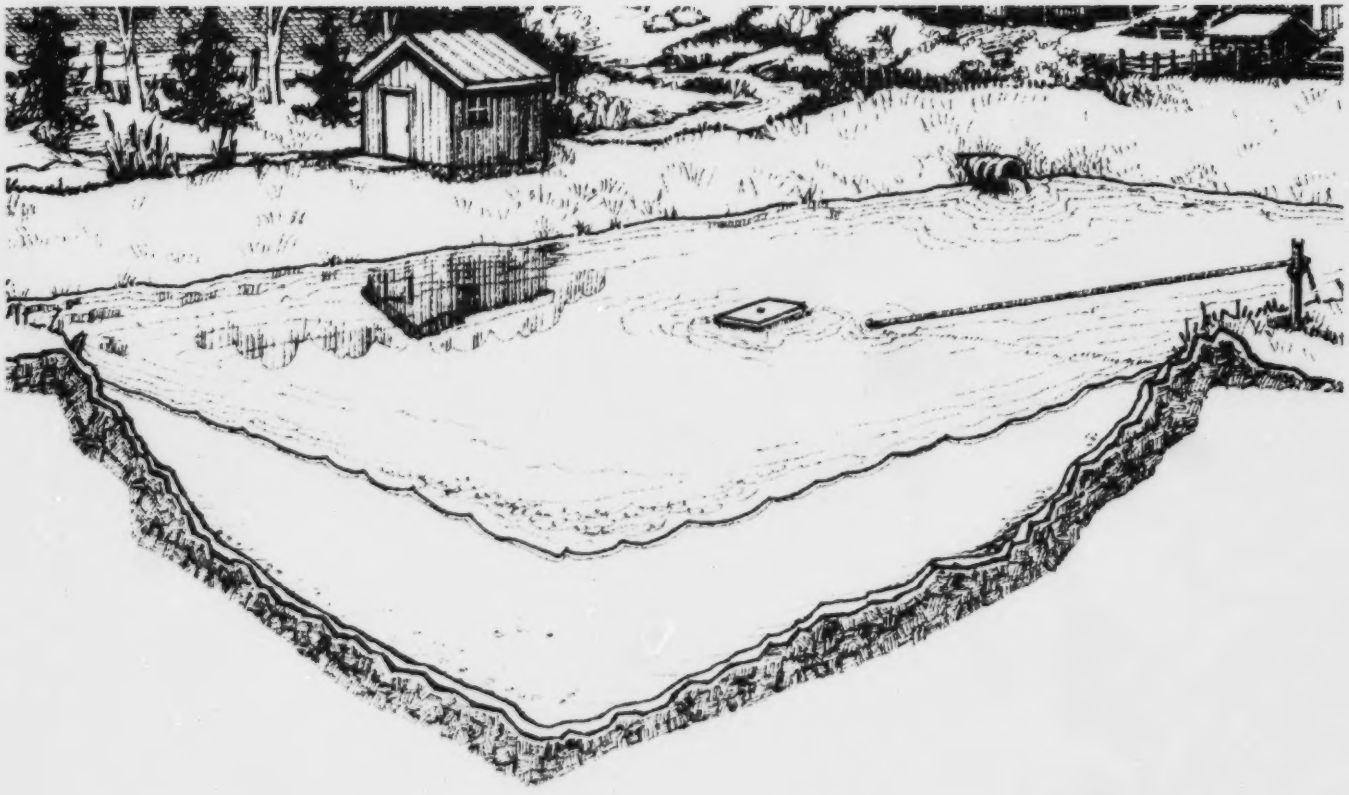
In 1999, Health Canada conducted the "Survey of Drinking Water Treatment Services Available on the Canadian Retail Market". The survey covered seventeen cities across Canada including seven cities on the Prairies. The treatment devices studied included softeners, distillers, reverse osmosis systems, filtration systems, microbial purifiers, and UV systems. About half the devices surveyed were filtration systems, and about one-quarter were reverse osmosis systems. The devices were divided into three groups:

- treatment devices for disinfecting water contaminated by microorganisms
- treatment devices for improving taste, odour, and appearance
- treatment devices for removing chemical contaminants.

Health Canada Survey of Treatment Devices	
Models surveyed	318
Certified	34.0%
Uncertified	62.0%
Not NSF, but bearing name/logo	4.0%

The survey indicates that only one-third of the devices sold by retail have been tested and certified by professional testing agencies such as NSF, CSA, or UL. This leaves many questions unanswered as to the effectiveness and reliability of such devices in the treatment of dugout water.

Dugout Management



The goal of dugout management is to protect and improve water quality. Some of the strategies for doing this through dugout location and design have been discussed in Module 3 – Planning. This module provides suggestions for preserving and enhancing water quality in existing dugouts. The cost and effort to properly manage a dugout is generally small and most often rapidly recovered in the form of improvements in water quality. Improving water quality reduces treatment costs, improves productivity of livestock, and generally improves the quality of rural life.

At a minimum, dugouts need to be inspected weekly during April to September and monthly from October to March. Early detection of problems allows corrective action before water quality deteriorates significantly. When inspecting, look for:

- any peculiar signs of animal entry
- signs of failure of the aeration systems
- incorrect positioning of the water intake
- algae growth or blooms, and increased plant growth
- damage to grass buffer areas and diking
- signs of contaminated runoff.

Keep a record of your inspections. This will enable you to document and analyze both short-term and long-term occurrences. The example in Figure 45 shows a filled out Dugout Maintenance Schedule. Review the example to see the type of information recorded. Use the blank form located in the pocket at the rear of the manual to record dugout inspections.

Figure 45 Dugout Maintenance Schedule

Dugout Maintenance Schedule

Year: *2000 - 2001* Dugout No.: *1* Legal Land Description: *NW 30-50-30 W4*

Season	Date	Water Level	Comments (runoff, water quality, treatment, and maintenance)
Spring	*March 25*	*4 ft from full*	*- very little runoff only added 2 ft of water* *- increase in sediment in water* *- checked aeration pump*
Summer	*June 15*	*5 ft from full*	*- water clarity decreased because of cyanobacteria growth* *- treated dugout with 3 pounds of copper sulphate to control cyanobacteria*
	July 17	*6 ft from full*	*- spot treated water weeds around dugout edge with 1/2 liter of Reward (diquat)*
	Aug 12	*7 ft from full*	*- water clarity decreased* *- re-treated for cyanobacteria with 3 pounds of copper sulphate*
Fall	*Oct 5*	*7.5 ft from full*	*- approximately a 10 foot depth of water left in dugout which will be adequate for winter use* *- pulled floating intake to bank and cleaned perforations* *- thoroughly checked dugout aeration pump diaphragm, and checked valves in preparation for winter* *- ensured runoff control gate opens and closes in preparation for next spring's runoff*
Winter	*Jan 15*	*10 ft from full*	*- about a 5 foot depth of water below ice* *- checked aeration pump*
	Mar 1	*11.5 ft from full*	*- open runoff control gate prior to spring runoff*

Summary of comments for the year and proposed improvements changes

Water levels were very low because of the lack of spring runoff and high evaporation losses

Try to increase runoff into dugout with additional snow fencing and make plans to [illegible]

Need to clean the diffuser as it seems to be restricting air flow into the dugout

Figure 45 Dugout Maintenance Schedule

Dugout Maintenance Schedule

Year: *2000 - 2001* Dugout No.: *1* Legal Land Description: *NW 30-50-30-W4*

Season	Date	Water Level	Comments (runoff, water quality, treatment, and maintenance)
Spring	*March 25*	*4 ft from full*	*- very little runoff only added 2 ft of water* *- increase in sediment in water* *- checked aeration pump*
Summer	*June 15*	*5 ft from full*	*- water clarity decreased because of cyanobacteria growth* *- treated dugout with 3 pounds of copper sulphate to control cyanobacteria*
	July 17	*6 ft from full*	*- spot treated water weeds around dugout edge with 1/2 liter of Reward (diquat)*
	Aug 12	*7 ft from full*	*- water clarity decreased* *- re-treated for cyanobacteria with 3 pounds of copper sulphate*
Fall	*Oct 5*	*7.5 ft from full*	*- approximately a 10 foot depth of water left in dugout which will be adequate for winter use* *- pulled floating intake to bank and cleaned perforations* *- thoroughly checked dugout aeration pump diaphragm, and checked valves in preparation for winter* *- ensured runoff control gate opens and closes in preparation for next spring's runoff*
Winter	*Jan 15*	*10 ft from full*	*- about a 5 foot depth of water below ice* *- checked aeration pump*
	Mar 1	*11.5 ft from full*	*- open runoff control gate prior to spring runoff*

Summary of comments for the year and proposed improvements/changes

- Water levels were very low because of the lack of spring runoff and high evaporation losses.

- Try to increase runoff into dugout with additional snow fencing and make plans for new shelterbelt.

- Need to clean air diffuser as it seems to be restricting air flow into the dugout.

Dugout Management Practices

There are a great number of dugout management practices. Many are known to be highly effective, while others are still in the experimental stages. Some techniques are common sense and do not require special or highly processed products or services. Other treatments involve chemicals and make use of commercial products. This module outlines some of these practices, including their strengths and weaknesses.

Established Practices

The practices presented in this module are well-established methods of greatly improving dugout water quality.

Continuous Aeration

Continuous injection of supplementary oxygen is the single most effective practice for maintaining and improving water quality. Aeration is discussed further on page 52 in Module 5 – Operating Systems, Dugout Aeration Systems.

Sediment Removal

Excavation of accumulated sediment from a dugout, every five to ten years, is an effective technique for improving water quality and extending the life of a dugout. Unfortunately, it is costly and excavation may exceed the cost of new dugout construction. Make careful cost estimates prior to deciding to clean out a dugout. Where two or more dugouts exist, divert all runoff away from the dugout to be excavated. Let the dugout dry up during summer, and excavate the sediment in early fall. Where only one dugout exists, the only way to excavate sediment under water is with a dragline or hydraulic backhoe. After excavation under water, expect the water to have high turbidity for up to several weeks or perhaps months.

Vegetation Control

Routine maintenance of the area around a dugout is important for maintaining water quality. Grassed buffers and runways surrounding dugouts should be mowed regularly. This prevents long grass from lying down and becoming ineffective as a sediment trap. Proper setback of shelterbelts ensures that the amount of fallen leaves entering the water is at a minimum. Steep

end-slopes reduce the amount of emergent plants than can grow in the dugout. If possible, aquatic plants should be removed from the dugout before they die and decompose. Shrubs and trees will take root on the banks of the dugout. Left alone, they can grow quite large and contribute significant amounts of vegetation to the water in fall. Annual cutting and removing of willows and volunteer saplings every fall can make a significant contribution to protecting dugout water.

Removal of Animals

Animals such as salamanders, also called mud puppies, and muskrats can create problems in a dugout by burrowing, house building, and foraging for plant roots. This disturbs the sediments and keeps the water constantly turbid. The most effective way to remove muskrats is trapping or hunting. Specially designed fencing can be used to keep them out in the first place.

Copper Sulphate

Copper sulphate, also known as **bluestone**, is perhaps the most common chemical used to treat dugouts as shown in Figure 46. It is also the least understood. Copper is an essential element for both plants and animals, but at high concentrations, it can be toxic. Copper treatments can be very effective at controlling cyanobacteria. However, copper sulphate treatments are most effective when done in early summer before large populations develop.

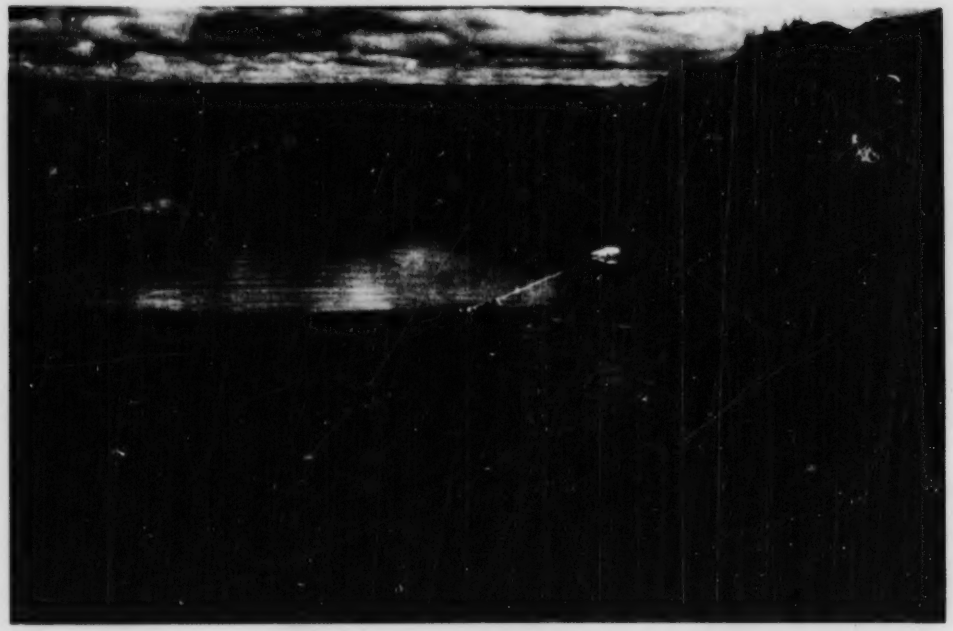
Copper may also kill beneficial organisms, like zooplankton, which feed on some algae species. Overuse and repeated treatments can also cause a build-up of copper in the sediments of a dugout. This can harm or kill beneficial organisms and disrupt the normal biology of the dugout. In fact, a single overdose can also cause a man-made green algae bloom.

Don't overdose! *Copper is not effective on green algae!*

Health Canada recommends that the concentration of copper in drinking water for humans not exceed 1 mg/L copper. However, this is far below what would be a toxic level.

Copper treatments should therefore be done very selectively. It is not reasonable to expect dugouts to be completely free of green or brown algae, nor free of aquatic plants. The primary target organism of a copper treatment is cyanobacteria. If copper is applied during an algae bloom, there may be an immediate release of large quantities of toxin. Because of the toxins they produce, it is recommended that you wait a minimum of 14 days before the water is used for human or animal consumption. This should allow toxin levels to dissipate. Continuous diffused aeration during this period may also help degrade toxins.

Figure 46 Bluestone Treatment

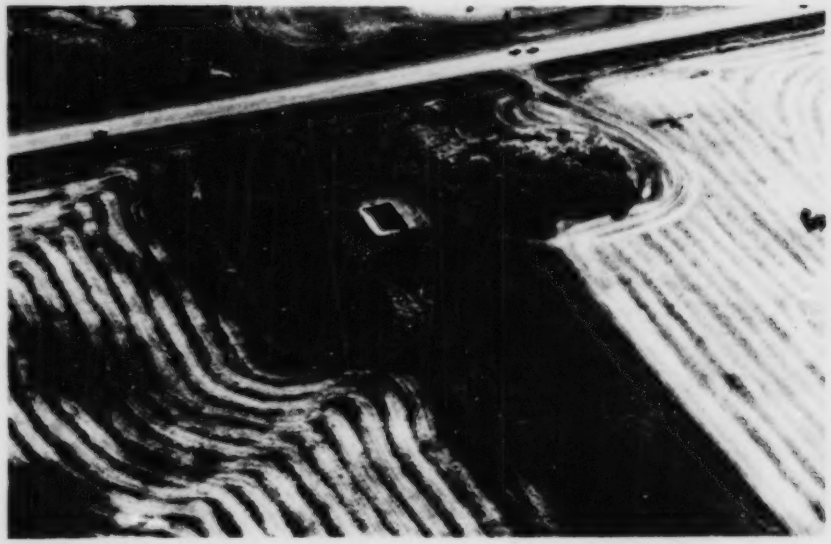


Copper is found in a variety of products. The active ingredient is always the copper element (Cu) itself. As of December 2000, copper products registered by the Canada Pest Management Regulatory Agency for control of algae in dugouts include:

- Algi-Boss Algicide Solution
- Nalco Cuprous Algae Control Chemical
- Cominco Cupric Sulphate Pentahydrate
- Polydex Bacteriostatic Algicide
- Cutrine Plus Liquid Algicide
- Cutrine Plus Granular Algicide
- Phelps Dodge Triangle Brand granular

More information about copper products and procedures for treating dugouts is provided on page 117 in Appendix 3 Using Copper Products to Control Cyanobacteria.

Figure 47 Coagulation Cell



Coagulation

The coagulation process is outlined in Module 7 – Water Treatment for Domestic Water Supplies. As opposed to treating the entire dugout, it is more economical to treat the small volume of water required for high quality use in a specially constructed treatment cell, separate from the dugout as shown in Figure 47. However, coagulation chemicals have successfully treated entire dugouts and have remediated flood affected turbid dugouts. The addition of Powdered Activated Carbon has proven to be helpful for increased removal of dissolved organic matter, taste, and odour compounds. If a dugout is coagulated regularly, chemical residues should be monitored.

Herbicides

Only two herbicides are registered for use by the Canada Pest Management Regulatory Agency to control aquatic weeds and algae: Reward A and Karmex DF. These compounds may only be used on privately owned reservoirs where water does not flow into other water bodies, as shown in Figure 48 Herbicide Treatment. Always follow label directions, and use safe handling practices to protect yourself from the product. In order to calculate the proper dosage, you must accurately estimate the existing volume of water in the dugout to be treated.

Figure 48 Herbicide Treatment

Reward

Reward is a non-selective herbicide with diquat as the active ingredient. Following treatment, the water should not be used for human or animal consumption for two weeks. This will allow for dissipation of the chemical as well as potential cyanobacteria toxins that may have been released by the treatment. A five-day wait is suggested if the water is to be used for irrigation. This is to protect irrigated plants from being damaged by residual herbicide concentrations. Reward is a new formulation of diquat that replaces Reglone A.

Karmex DF

Karmex DF is a non-selective, systemic herbicide with diuron as the active ingredient. It is licensed for use in Canada primarily for use in ornamental water bodies. It is not registered for dugouts used for domestic water supplies, or dugouts with fish, where the fish may be used for human or livestock consumption. Although not provided as a specific safety precaution by the manufacturer, treated water is probably not suitable for watering livestock. Water treated with Karmex DF should not be used as irrigation water for a minimum of 12 months. Nor should it be applied to dugouts or ponds with desirable trees or shrubs around the perimeter as roots may take up the herbicide from the water and cause injury to the plants.

Experimental Practices

A number of practices are being tried to manage dugout water quality. Research into their feasibility and effectiveness is ongoing. Although this module outlines some of these practices, they cannot be recommended at this time.

Dugout Covers

Floating synthetic plastic dugout covers, as shown in Figure 49, have been used experimentally on dugouts to prevent algae and plant growth by limiting light penetration into the water and to minimize evaporative losses. Plastic tarp-like covers are floated on top of the water and anchored to the banks at several points. Since the water level in the dugout will vary during the year, the anchor straps must be left slack or adjusted on a regular basis to allow for fluctuating water levels. Individuals who have used dugout covers have reported a significant reduction of evaporative losses in periods of drought.

Figure 49 Dugout Cover

Supplemental diffused aeration is essential to maintain oxygen levels in a covered dugout. Well-designed covers are perforated with special slits to release any accumulated air from the aeration system that collects underneath the tarp. Due to the nature of these slits, they allow the release of air while preventing the passage of light through the perforations. Dugout covers have a life expectancy of only three to five years due to degradation by ultraviolet light, but problems can arise sooner from wind and ice damage. If tarp anchors are not properly adjusted, wind can destroy a dugout cover.

Disinfectants

Disinfectants are chemicals containing concentrated oxidants, such as chlorine, hydrogen peroxide, and ozone. They are effective at killing micro-organisms when:

- the water is clean enough
- the dosage is strong enough
- the contact time is long enough.

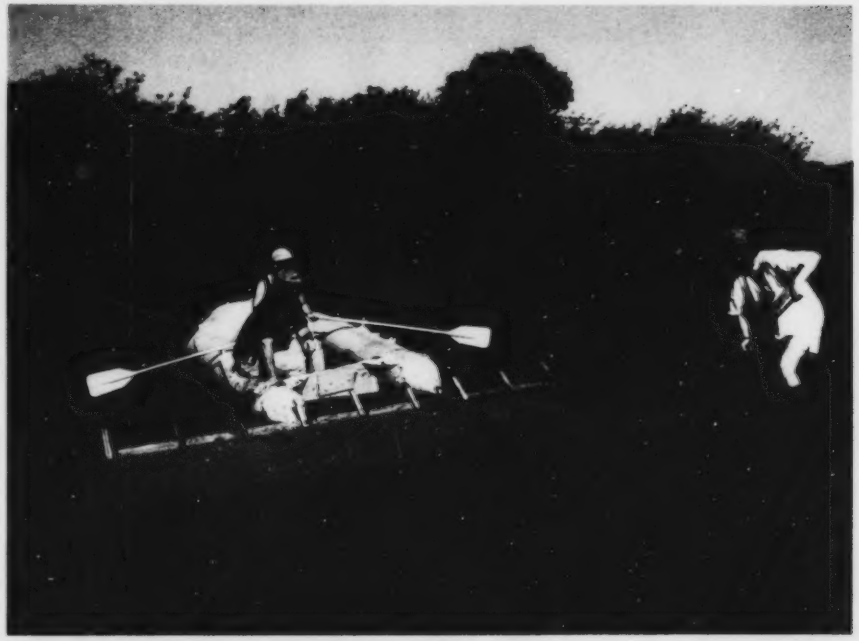
However, disinfectants are non-selective and will kill off many beneficial organisms. Accordingly, they are not registered for use in dugouts, although they are widely used in water treatment plants.

Plants

Plants have been used experimentally to improve water quality. Some species of aquatic plants may improve summer water quality by taking up nitrogen and phosphorus. With the fertility of the water reduced, the growth of unwanted algae species may be suppressed. Rooted plants such as cattails can serve this purpose. However, in order to maintain the water quality, the plants must be removed in the fall. If not removed, the plants will eventually die off, and plant nutrients will be returned to the water.

Because bottom-rooted plants can be difficult to harvest, there is interest in using floating plants to improve water quality. Duckweed is a floating, native plant that is able to take up large amounts of phosphorus from water but must be constantly harvested and removed from the dugout. It only survives in relatively sheltered locations and often blows to the downwind side of a water body. Water hyacinth is a floating, tropical plant that has only been used experimentally on Canadian dugouts to reduce algae problems. Both duckweed and water hyacinth can be harvested using a floating boom, as shown in the Figure 50..

Figure 50 Harvesting Duckweed



Harvesting can be accomplished by dragging a floating timber boom across the dugout to the opposite shore, and removing the plants.

Fish

Fish are sometimes added to dugouts to improve water quality by eating aquatic plants. However, they may often compound dugout, water quality problems by making it difficult to use other chemical methods of algae and plant control.

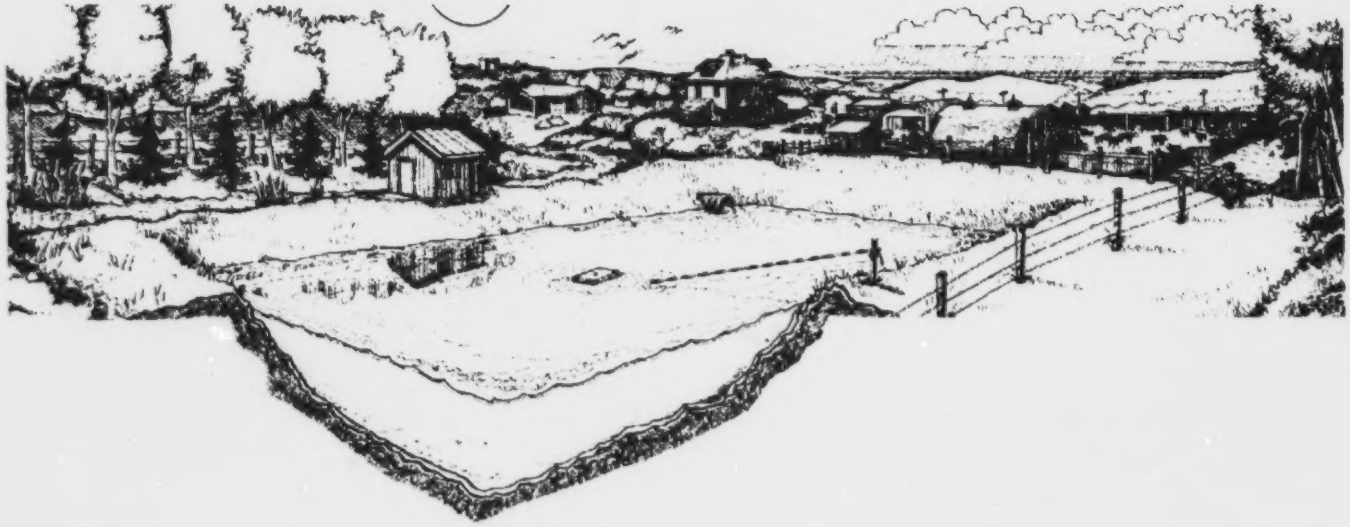
For the same reasons that plants should be removed from a dugout, fish should be harvested before they die and decompose. Grass carp or *Tilapia* are effective at removing plants in dugouts but because of concern about the possibility of escape into the wild, their use is not permitted in some provinces. Check with provincial authorities before considering the addition of fish to a dugout. Some fish, notably rainbow trout, can actually degrade water quality by eating phytoplankton and adding excrement to the water.

Miscellaneous Biological and Chemical Products

There are a number of products now available on the market that advertise the ability to improve water quality. Many of these products have been developed for non-consumptive ponds such as golf courses, ornamental ponds, and zoo ponds. The range of products includes bacteria, chemical toxins, and light inhibiting dyes. Check for registration with the Canada Pest Management Regulatory Agency of Health Canada, and if registered, check the registration/certification information for any specified water use limitations.

The vast majority of these products are **not** registered by the Canada Pest Management Regulatory Agency for application to dugouts or farm ponds used for consumptive purposes. Until research proves the effectiveness and safety of these chemicals in dugouts, their use is not recommended.

Trouble Shooting Guide for Dugout Problems



Dugout problems fall into two broad categories: water quantity and water quality. Problems can result from the watershed; the dugout location, design, and construction; the systems and equipment for pumping, aeration, and treatment; as well as management practices. This module is designed to identify the source of a problem and provide suggestions for correction. The troubleshooting guide starts by identifying typical symptoms of water quantity or quality problems. It systematically lists possible causes, identification features, suggestions for corrective action, and references for further information within the manual.

Symptom 1 Low Dugout Water Levels

Possible Causes	What to Check For	How to Correct (Options)	For More Information See Section On:
Inadequate watershed	• observe or measure the area contributing water to the dugout during runoff events.	• enhance snow trapping in the watershed with shelterbelts, snow fences or crop stubble	• Watershed Runoff Potential and Dugout Sizing, page 19.
		• pump water to fill dugout	• Appendix 4 Contacts and References, page 119.
		• develop another water source	• Planning Farm Water Supplies, page 18.
Drought	• what are normal snow and rainfall amounts for your area? Information available from Environment Canada	• snow trapping • pump water from another source • increase water storage • develop another water source (back up) for drought proofing purposes	• Watershed Runoff Potential and Dugout Sizing, page 19.
Dugout too small	• compare annual water use and ice and evaporation losses with dugout size recommended • consider any future expansion, etc. • steady drop in water levels	• increase dugout source and add another source	• Watershed Runoff Potential and Dugout Sizing, page 19.
Seepage from dugout	• sand lenses or layers of silts and fractured clay	• use dugout sealing techniques • relocate dugout to suitable soil condition	• Large Scale Sealing Methods and Materials, pages 35–37.
Soil depositing in dugout	• soil erosion in watershed or watercourses draining to dugout	• use soil erosion techniques such as a grass cover and gated culvert inlets to the dugout to prevent sedimentation • remove sediment from dugout with a large trackhoe or dragline • use a 2 dugout system: one for a settling pond and the second for use	• Water Quality and Watershed Management, pages 25–27. • Dugout Design, page 32–34. • Sediment Removal, page 88. • Sedimentation Dugouts, page 33.

Possible Causes	What to Check For	How to Correct (Options)	For More Information See Section On:
Upstream blockages or drainage	• upstream beaver dams, snow damming or sediment blockages in water courses	• use a tractor to remove snow dams or drifts that re-direct water runoff	
	• upstream drainage or diversion reducing runoff to dugout	• contact appropriate agencies responsible for beaver control and/ or watercourse changes	• Appendix 4, Contacts and References, page 119.
		• contact provincial government agencies responsible for drainage approvals	• Appendix 4, Contacts and Reference, page 119.

Symptom 2 Human or Animal Sickness Caused by Water Contamination

Possible Causes	What to Check For	How to Correct (Options)	For More Information See Section On:
Water Contamination	• identify potential sources of contamination in the runoff area and seek professional advice on specific test parameters.	• discontinue using the water source and consult local health unit, doctor or veterinarian for their assistance	• Health Risks and Water Quality, pages 60–62. • Standard Testing of Drinking Water, pages 64–66.
		• remove the source of contamination wherever possible and replace gravel trench filters with floating dugout intakes	• Health Risks and Water Quality, pages 60–62. • Intake Systems, pages 44–46.
		• seek advice from water treatment specialists.	• Steps in Water Treatment, pages 70–74.
		• provide another source of uncontaminated water or install appropriate water treatment equipment	• Steps in Water Treatment. pages 70–74.
		• install filtration and disinfection equipment	• Steps in Water Treatment, pages 70–74.
		• install polishing treatment equipment, such as R.O. or water distillers	• Steps in Water Treatment, pages 70–74.
		• install cistern to haul in water for household use and drinking	

Symptom 3 Black Smelly Water in Dugout

[illegible]	What to Check For	How to Control (Options)	For More Information See Section One
Depletion of dissolved oxygen levels in dugout water (summer)	• abundant algae and weed growth and decay • cyanobacteria growth • grass clipping appearance to water • dark green slime floating or deposited along dugout banks	• control algae and weed growth by employing control techniques • replenish oxygen with dugout aeration system	• Dugout Management Practices, pages 88–96. • Dugout Aeration Systems, pages 52–56.
	• dirty water after runoff and reduced water depths in dugout	• employ soil erosion techniques in watershed or watercourses, gated inlets or two dugout system	• Sedimentation Dugouts, page 33. • Water Quality and Watershed Management , pages 25–27.
		• clean dugout with excavation equipment and steepen all slopes to reduce weed and algal growth	• Sediment Removal, page 88.
	• organic plant material deposited in dugout	• use screened culvert inlets and locate deciduous trees away from dugout	• Vegetation Control, page 88.
	• recycling of nutrients from dugout sediments causing increased algal growth	• ensure dugout aeration is diffused at the dugout bottom • use a perforated pipe or device to diffuse oxygen instead of open ended hose	• Dugout Aeration Systems, pages 52–56. • Dugout Aeration Systems, pages 52–56.
	• water intake near dugout bottom	• raise floating intake near surface	• Intake Systems, pages 44–46.
	• deterioration of water quality in wet well	• clean out large-diameter wet wells or abandon in favour of small-diameter wet wells	• Wet Well, page 47.

Depletion of dissolved oxygen levels in dugout water (winter)	• dugout aeration equipment not installed or working properly • snow cover on dugout reducing sunlight and oxygen produced by growing plants	• check and maintain dugout aeration equipment • where feasible carefully clean snow-cover from a portion of dugout surface	• Dugout Aeration Systems, pages 52–56.
Black smelly water after Home Treatment System only	• filter system fouled with organic material and organic sediments in pressure tank and/or hot water	• clean or replace filter medium • ensure adequate disinfection of water	• Steps in Water Treatment, pages 72–74.
Bottom dugout water entering from damaged intake pipe	• damaged intake pipe • hire a diver to repair water intake pipe	• hire a diver to repair water intake pipe	• Steps in Water Treatment, pages 72–74.

Symptom 4 Dirty Dugout Water

Possible Cause	What to Check For	How to Correct (Options)	For More Information See Section On:
Soil erosion of watershed and watercourses	• soil erosion • recent runoff event • suspended clay particles that will not settle	• employ soil erosion techniques and gated inlet • use a two dugout system • use coagulants in dugout to clear water	• Dugout Design, pages 32–33. • Water Quality and Watershed Management, pages 25–27. • Sedimentation Dugout, page 33. • Coagulation, page 91.
Erosion in dugout	• soil erosion by wave action	• protect eroded dugout banks with erosion prevention materials like filter cloth, plastic, or riprap • install water treatment system including coagulants and sand filter	• Dugout Construction, page 35. • Steps in Water Treatment, pages 70–74.
Muskrats, ducks, mud-puppies	• abundance of cattails and tunnels into dugout banks • floating cattails	• control cattails and remove muskrats by trapping, etc.	• Dugout Management Practices, pages 88–89.
Contaminated Runoff	• test water for bacteria, chemicals and pesticides	• remove contaminants and/or cause from watershed • divert any contaminated runoff around dugout • install water treatment equipment	• Dugout Water Quality, and Watershed Management, pages 25–27. • Steps in Water Treatment, pages 70–74.
Human Activity	• swimming	• eliminate swimming	

Symptom 5 Discoloured Water and Staining

Possible Cause	What to Check For	How to Correct (Options)	For More Information See Section On:
Iron in Water	• brown to rusty coloured stains on clothes and plumbing fixtures	• install dugout aeration system and/or iron removal treatment equipment if required • replace gravel trench filters with floating water intakes	• Dugout Aeration Systems, pages 52–56. • Steps in Water Treatment, pages 70–76. • Intake Systems, pages 44–46.
Organic Matter in Water	• sloughy conditions around dugout	• prevent flooding and slough conditions • re-locate dugout	
	• staining • abundance of organic material and peat soil in watershed or dugout area	• coagulation treatment • re-locate dugout • cover organic material around the dugout with clay soil and grass cover	
	• decomposing plants and animals • excessive plant and algal growth in dugout	• install aeration equipment • use gated inlet to allow clear water into dugout • control nutrients coming into dugout which encourage plant and algal growth	• Dugout Aeration, pages 52–56. • Dugout Design, pages 32–33. • Water Quality and Watershed Management, pages 25–27.
	• green to yellow colour (dissolved or particulate organic colour)	• control algae and plant growth with a combination of biological, physical and chemical methods • install aeration equipment	• Dugout Management, pages 88–96.
	• shallow dugout with flat slopes	• steepen dugout slopes and deepen dugout	• Dugout Construction, page 35.
	• watershed/watercourse vegetation containing clover etc. • excessive dosages of chemicals including copper sulphate for algal control resulting in man-made blooms of green algae	• avoid planting vegetation that imparts colour • reduce/eliminate chemical dosages and allow zooplankton to re-establish and control green algae	• Water Quality and Watershed Management, pages 25–27. • Appendix 3 Using Copper Products..., pages 117–118.
	• test for dissolved organic carbon	• use coagulants in the dugout or in home treatment to remove	• Steps in Water Treatment, pages 70–74.

Symptom 6 Mineral Scale and Grey Discolouring of Clothes

Calcium and magnesium hardness	• scale on plumbing fixtures, humidifier • grey colouring of clothes • test for hardness • gravel infiltration trench	• install ion-exchange water softener • use water additives such as Calgon, etc. • install a direct intake	• Steps in Water Treatment, pages 70–74. • Intake Systems, pages 44–46.

Symptom 7 Taste and Odour in Water

Iron in water	• refer to Symptom 5 for comments		
Sloughy, musty, fishy smell	• algal growth	• use algal control techniques • install activated carbon filtration	• Dugout Management, pages 88–96. • Steps in Water Treatment , pages 70–74.
Rotten egg smell	• refer to Symptom 3 for comments		
Salty, bitter taste	• high total dissolved solids caused by groundwater seepage or increased mineralization in gravel trench	• prevent poor quality water from seeping into dugout or relocate dugout • replace gravel filter trench with floating water intake	• Planning, pages 29–30. • Intake Systems, pages 44–46.

Glossary

absorption – a process by which one substance is trapped **throughout** the volume of another, usually a liquid by a solution.

adsorption – a process by which a substance is trapped **on** the surface of a solid substance.

algae – single-celled plants, capable of photosynthesis.

alkalinity – the ability of a solution to neutralize acids.

aquaculture – production of aquatic plants or animals, particularly fish, for commercial purposes.

aquifer – an underground layer of relatively porous, saturated soil or rock that is capable of yielding a useful supply of water.

backwashing – the cleaning cycle of a water treatment system where clean water is forced back through the filter media.

bacteria – single-celled organisms that do not contain chlorophyll and are not capable of photosynthesis.

bentonite – a swelling clay used to construct liners for lagoons and dugouts.

blue-green algae – common expression used to refer to cyanobacteria, an aquatic microorganism which can produce powerful toxins.

bluestone – copper sulphate

BMPs – best management practices

coagulation – the addition of certain chemicals to water that allow very small particles to collide, stick together, and form flocs.

cfm – cubic foot per minute

coliform – a common group of bacteria used as a biological indicator of water pollution.

contour planting – planting crops in rows that are at right angles to the direction of the slope.

cryptosporidia – a single-celled, disease-causing, parasite whose life-cycle includes a cyst-forming phase which allows the organism to survive in harsh environments.

cyanobacteria – single-celled organisms that are capable of photosynthesis but are more closely related to bacteria than plants. They are often referred to as 'blue-green algae'.

diffuser – a device for introducing small air bubbles into water.

disinfection – the process of eliminating nearly all disease-causing organisms from water.

duckweed – a floating green plant that obtains nutrients from the water using dangling roots. It often forms large floating mats.

E. coli – a species of fecal coliform bacteria, some strains of which cause disease in humans. The strain, *E. coli 0157:H7,* has been identified as the pathogen in the Walkerton water supply.

fecal coliform – coliform bacteria that live in the intestines of warm-blooded animals.

floc – a particle formed in coagulation-flocculation process which is large enough to settle out of water.

geo-textile – a manufactured material used to protect soil surfaces from erosion.

gpm – gallons per minute.

giardia – a single-celled, disease-causing parasite whose life-cycle includes a cyst-forming phase which allows it to survive in harsh environments. The disease is commonly referred to as 'beaver fever'.

gleization – a dugout sealing technique which involves packing a layer of clay over a layer of organic matter. The term is derived from a natural soil-forming process.

integrated pest management – a system of agricultural pest management based on a wide variety of practices and control measures that are economically feasible and environmentally sound.

lift – when applied to water pumping, lift indicates the distance or elevation water is to be moved vertically.

mg/L – milligrams per liter.

mIg – million Imperial gallons.

nutrient management – a system of fertilizer management that minimizes the amount of fertilizer applied on a farm.

ozonation – a process of water disinfection that uses ozone. Ozone is the next most powerful oxidant after fluorine.

pathogen – a microorganism that can cause disease.

pH – pH is a measure of the acidity of a solution. It is measured on a logarithmic scale from 1 to 14. Solutions of pH 7 are neutral, solutions below 7 are acidic and solutions above 7 are basic.

phosphorus – an essential plant nutrient but one that often causes algae blooms when an excess is present in a water-body.

pitless adapter – a mechanical device designed to provide frost-free, sanitary well conditions.

psi – pounds per square inch.

plant nutrients – mineral elements required by plants.

point-of-entry treatment – a system used to treat all or part of the water at the inlet to a facility.

point-of-use treatment – a plumbed-in or faucet-mounted system used to treat water at a single tap or multiple taps but not used to treat all the water for a facility.

pressure tank – a component of a water distribution system which holds water at higher than atmospheric pressure.

protozoa – single-celled microorganisms that consume bacteria and algae.

reverse osmosis (RO) treatment – a system used to remove dissolved solids from water.

riprap – a wall or bank of stones used to provide strength and prevent erosion.

submersible pump – a centrifugal pump which is run by an electric motor and operates while submerged under water.

total dissolved solids (TDS) – the sum of the weights of all mineral compounds dissolved in a specific volume of water.

turbidity – a measure of the light-scattering effect of small particles suspended in water.

ultra-violet disinfection – a water purification process using ultraviolet (UV) light to kill microorganisms by disrupting their DNA and preventing reproduction. In order to be effective, UV must actually strike the cell.

virus – a large group submicroscopic organisms consisting only of a core of RNA or DNA which is surrounded by a protein coat. Many viruses cause disease in humans.

Watershed – the area of land that drains runoff to a point on a stream or other water body. Also called a drainage basin.

wet well – a structure installed next to a surface water supply, rather than directly in it, to provide a safe and convenient location for a distribution pump.

zooplankton – a diverse group of tiny aquatic animals that feed on algae and bacteria.

Appendix 1 Provincial Regulations

Alberta

Water Licensing

The *Water Act* establishes that the Crown, the Province of Alberta, has ownership of all water. In Alberta, no license is required for household purposes **up to** 275,000 imperial gallons (1250 cubic meters of water) per year. Under the *Water Act*, household purposes are defined as water used for human consumption, sanitation, fire prevention, and watering animals, gardens, lawns, and trees.

Using water from dugouts is exempt from licensing if:

- Water is naturally impounded in the dugout from surface water runoff and no pumping has been done to facilitate the impoundment.
- The dugout is not situated within a watercourse, lake or wetland at any time.
- The capacity of the dugout is less than 2,750,000 imperial gallons (12,500 cubic meters).
- The total withdrawal of water from the dugout is less than 1,375,000 imperial gallons (6250 cubic meters) per year.

For more information, contact Alberta Environment in Edmonton.

Fish Stocking

Recreational and/or commercial licenses are required to stock fish in a dugout. The licenses are issued by the Aquaculture Section of Alberta Agriculture, Food and Rural Development. For more information, contact their office in Lethbridge. Licenses may also be required by Alberta Environment if dugouts are not used for household purposes and do not qualify under the exemption noted above.

Setbacks

Alberta Transportation requires a minimum setback of 40 meters (131 feet) from the highway property line on all primary and secondary highways. Local counties and municipalities also have similar setback distances from their roads for safety purposes. For further information, and to determine if a development permit is required, contact your local county or municipality office as well as the nearest Alberta Transportation office.

Technical and Financial Assistance

For technical assistance and information about possible funding opportunities, contact the nearest PFRA district office or Alberta Agriculture district office.

British Columbia

Water Licensing

Under the *Water Act*, water is owned by the province, and therefore, all water uses from a surface water source must be licensed. In the Peace River Region, however, the province has a license exemption for domestic and livestock watering dugouts, unless dugout construction involves changes in and about a stream as defined by the *Water Act*. All in-stream work requires a permit. If a dugout impounds water above ground level with a dyke or berm, it should be assessed using the dam safety regulations. For more information, contact the Ministry of Environment, Lands and Parks, Fort St. John.

Fish Stocking

A permit is required to stock fish in a dugout. The only species currently allowed for stocking in the Peace River Region is trout. Grass carp is prohibited. Permits are issued by the Federal/Provincial Fish Transplant Committee. For more information, contact the Ministry of Environment, Lands and Parks, Fort St. John.

Setbacks

The Ministry of Highways classifies a dugout as a structure; therefore a dugout must be a minimum of 25 feet (7.6 meters) from the edge of the road allowance, or 150 feet (45.6 meters) from the center of the road. For more information, contact the Department of Highways, Dawson Creek.

The Peace River Regional District should also be contacted regarding potential setbacks between or adjacent to property lines. These setbacks are site specific and have no set parameters. For more information, contact the Peace River Regional District.

Technical and Financial Assistance

For technical assistance and information about possible funding opportunities, contact the nearest PFRA district office or British Columbia Ministry of Agriculture and Food, Fort St. John.

Manitoba

Water Licensing

Ownership of surface and groundwater is vested in the province of Manitoba. The size, location, and intended use determine the licensing requirements for water storage and use in Manitoba. Domestic use does not require approval. Domestic use is defined as rural household and livestock consumption up to 5500 imperial gallons (25,000 liters) per day. For more information, contact Water Rights Licensing Section, Manitoba Conservation, Winnipeg.

Fish Stocking

Aquaculture operations involving fish hatcheries require licensing and provincial environmental assessment. Dugouts used for commercial fishery operations also require a Fish Farming License. For more information, contact the Manitoba Fisheries Branch, Manitoba Conservation, Winnipeg.

Setbacks

The siting of dugouts closer than prescribed distances to provincial highways and roads requires a permit. Generally, minimum setback distances range from 125 to 250 feet (40 to 75 meters) unless the site is adjacent to an intersection control circle, in which case the required setback ranges from 500 to 1500 feet (150 to 450 meters). Each permit is assessed individually with consideration given to future highway development and highway safety requirements. For more information, contact the Highways and Government Services, Highway Planning and Design Branch, Winnipeg.

Technical and Financial Assistance

For technical assistance and information about possible funding opportunities, contact the nearest PFRA district office or Manitoba Water Services Board.

Saskatchewan

Water Licensing

Ownership of all surface and groundwater is vested in the Province of Saskatchewan through the *Water Corporation Act*. The act requires that approval to construct, followed by an approval to operate, must be issued for any commercial, municipal, irrigation, or tank-loading facility dugout. No approvals are required for construction or use if the dugout is intended for domestic purposes as defined by the *Water Corporation Act*. However, on a domestic dugout, if a dam or diversion ditch is constructed to divert water from a natural watercourse or water-body to the dugout, then an "Approval to Construct and Operate" is required. Approvals to construct and operate a dugout are issued through Sask Water, Regional Water Resource offices in Saskatchewan.

Fish Stocking

If a dugout is private and contained with no potential discharge, it may be stocked with certain types of fish. A list of permitted fish is available from your local Saskatchewan Environment and Resource Management (SERM) office. Dugouts in Saskatchewan may not be stocked with native fish such as walleye, pike, and pickerel. If there is a potential discharge from the dugout into the waterway, fish may not be stocked due to the potential spread of disease. Before stocking fish in a dugout, contact the local SERM office for up-to-date information.

Setbacks

Each Rural Municipality has its own regulations and bylaws governing the location of dugouts with respect to roads. If a dugout is to be situated near a road, prior approval must be obtained. The standard RM regulation is a distance of at least 150 feet (45 meters) from the centerline of the road. Refer to the RM office for further information

Technical and Financial Assistance

For technical assistance and information about possible funding opportunities, contact the nearest PFRA district office or Sask Water office.

Appendix 2 Water Quality Guide

Table 1 Causes and Symptoms of Some Waterborne Diseases

Disease	Microbiological Agent	Symptoms
Bacterial gastroenteritis	Bacteria –various organisms including *E. coli*	Diarrhea or bloody diarrhea, abdominal cramps, fever, nausea, vomiting
Campylobacteriosis	Bacteria – *campylobacter jejuni*	Fever, abdominal pain, diarrhea or bloody diarrhea, nausea, vomiting
Cryptosporidiosis	Protozoa – *cryptosporidia*	Diarrhea, abdominal discomfort, slight fever, nausea, vomiting, headaches
Cyclospora infection	Protozoa – cyclospora	Diarrhea, bloating, abdominal cramps, nausea, vomiting, fever
Giardiasis	Protozoa – giardia	Diarrhea, abdominal cramps, nausea, vomiting, chills, headache, fever
Hepatitis	Virus – hepatitis A	Fever, chills, abdominal pains, jaundice, dark urine
Shigellosis	Bacteria – shigella	Diarrhea, or bloody diarrhea, fever, abdominal cramps
Typhoid fever	Bacteria – *Salmonella typhi*	High fever, headache, constipation, loss of appetite, diarrhea, vomiting, abdominal rash
Viral gastroenteritis	Viruses – Norwalk type, rotaviruses, adenoviruses, enteroviruses	Diarrhea, vomiting, fever, headache, abdominal cramps

Table 2 Chemicals and Their Associated Risk to Human Health

Chemical	Source	Potential Health Effect	Canadian Drinking Water Quality Guideline (mg/L)
Aluminum	Natural deposits in earth and aluminum-based coagulants	Unknown; unproven links to Alzheimer's and Parkinson's diseases	Under review
Barium	Natural deposits in earth	Circulatory system effects	1
Boron	Natural deposits in earth	Damage to reproductive system	5
Copper	Natural deposits; corrosion products from piping	Gastrointestinal irritation at levels much higher than guideline	1*
Lead	Natural deposit and corrosion products from piping, solder, and some brass alloys	Damage to kidneys, reproductive and nervous systems; development damage in young children	0.01
Nitrate	Fertilizers; human or animal wastes	Methemoglobinemia in infants under six months; unproven link to some cancers	45
Pesticides (including various fungicides, herbicides, rodenticides and insecticides)	Agricultural activities (spraying and water runoff)	Various effects depending upon type of pesticide; suggested links to cancers, damage to liver, kidneys, nervous and reproductive systems	Varies depending upon pesticide (see Health Canada website or contact local health authority for specific details)
Petroleum hydrocarbons	Leak in fuel oil or gasoline tanks allowing seepage into water	Some hydrocarbons have been linked to various cancers, damage to liver, kidneys, nervous system	Under review
Phytoplankton toxins	Natural toxins produced and released by microscopic plants and algae	Liver and nervous system damage	Under review
Sodium*	Natural deposits in earth	Health risk only for individuals on salt-restricted diets	200**
Sulphate	Natural deposits in earth; some flocculants	At elevated levels causes laxative effect leading to dehydration	500***
Trihalomethanes	By-products of disinfection of water	Cancer	0.1****
Turbidity	Suspended mineral or organic material	Shelters pathogens from disinfection. Increases requirement for disinfectant	1 NTU*****

* Guideline established based on aesthetic quality. Adverse health effects are possible at levels much higher than guideline.

** Guideline established based on aesthetic quality. Adverse health effects possible only for those on salt-restricted diets.

*** Guideline established based on aesthetic quality. Consumption of water with elevated levels of sulphates may result in gastrointestinal irritation including diarrhea.

**** Average of four quarterly samples.

***** Nethelometric Turbidity Units

Table 3 Chemical Agents and Microbiological Species Affecting Aesthetic Quality of Water

Chemical/Species	Source	Symptom
Calcium	Natural deposits (limestone)	Hard water; scales and deposits in kettles and water heaters
Copper	Natural deposits; corrosion products from piping	Green staining of fixtures; metallic taste
Hydrogen Sulphide	Present in water with high iron content and low pH	Rotten egg odour
Iron	Natural deposits and iron-based coagulants	Rusty reddish-brown staining of fixtures and laundry; metallic taste
Iron bacteria	Bacteria feeding on iron in water	Reddish-brown slime on fixtures
Magnesium	Natural deposits	Hard water; scales and deposits in kettles and water heaters
Manganese	Natural deposits	Black staining of fixtures and laundry; metallic taste
Sodium	Natural deposits	Salty taste
Sulphate	Natural deposits; some flocculants	Objectionable taste
Sulphate	Bacteria feeding on sulphates in water	Rotten egg odour; blackish slime on fixtures
Tannins and Humic Acids	Natural organic matter (decaying plants and animals)	Various odours (aromatic, fishy, musty, earthy, woody) and tastes
Turbidity	Excessively fine sand or silt; runoff from soil	Abrasive texture to water; residue left in sink and tub
Zinc	Natural deposits; corrosion products from plumbing	Objectionable metallic taste

Appendix 3 Using Copper Products to Control Cyanobacteria

The Timing of Copper Treatment

Copper can be used to control cyanobacteria, often referred to as blue-green algae. If a treatment seems ineffective, do not repeat or increase the dose. Copper will not control green or brown algae.

Cyanobacteria grow fast when water temperature starts to rise, usually after a period of warm sunny weather. Always treat at the beginning of the bloom. This will provide much better control. If you treat with copper, always wait a minimum of two weeks before using the water. A waiting period is critical to allow any toxins from cyanobacteria to dissipate. Copper treatments are most successful when pH is between 7 and 8, alkalinity is between 50 to 150 mg/L, water temperature is above 15 degrees C, and the weather is sunny and calm. Never compensate for poor conditions by increasing the chemical dose - this can create serious water quality problems, and make the water unsafe or even dangerous for use.

Calculating a Copper Dose

Cyanobacteria use sunlight and live near the water surface. Therefore, it is only necessary to treat the top meter of water. A simple calculation can be used to approximate treatment volumes. Measure the surface length and width in meters, and multiply to get the volume of the top meter of water. Multiply by 1,000 to convert the volume from cubic meters into liters. The chemical that causes toxicity is called the active ingredient. Copper is the active ingredient in most products for controlling cyanobacteria. Different products have different amounts of actual copper in the formulation. The table below shows the relative amounts of different products required to deliver the recommended copper dosage of 0.25 mg/L to the top meter of water in a standard, as well as large, dugout.

Table 1 Equivalent Copper Application Rates for Chemicals Regulated by the Pest Management Regulatory Agency (Jan., 2001)

Item	Active Ingredient % Cu by Weight	Standard Dugouts (2 to 5 million Litres)	Large Dugouts (5 to 30 million Litres)
Dugout Example	–	20m x 50 m x 3.5m	50m x 150m x 6.0 m
Treatment Volume (Target the Top 1.0 m)	–	1.0 million L	7.5 million L
Top 1 m Treatment Dose	–	0.25 mg Cu/L	0.25 mg Cu/L
Copper Sulphate granular	25.4	1.0 kg	7.5 kg
Cominco Cupric granular	25.2	1.0 kg	7.5 kg
Phelps Dodge Triangle Brand granular	25.2	1.0 kg	7.5 kg
Cutrine Plus granular	3.7	6.8 kg	50.6 kg
Nalco Cuprose granular	19.1	1.3 kg	9.8 kg
Algi-Boss, liquid*	5.0	4.1 L	31.3 L
Cutrine Plus, liquid*	9.0	2.3 L	17.2 L
Polydex, liquid*	5.0	4.1 L	31.3 L

Note: Reduce all application rates by about 60% if fish are present.

How to Apply Copper Treatments

Although cyanobacteria may be controlled, over-dosing a dugout with copper may cause a subsequent increase in the growth of green and brown algae.

Use a safe target dose as recommended by Table 1, being careful not to exceed the label rate. Read the label and product literature for any restrictions on product use.

Dilute the required amount of copper product into a volume of water so that it can be sprayed over the surface of the dugout. Spray the entire surface, with particular focus to areas where cyanobacteria populations are greatest. Spraying can be done from shore or from a boat. Alternatively, dry copper chemical can be put into a nylon sock, with ropes tied to both ends of the sock. Drag the chemical sock back and forth along the top of the water, covering the entire surface area. The dry compound will dissolve in the water. Spot treatment is also possible using one teaspoon (5 ml) of dry copper sulphate added to 1 gallon (5 liters) of water. Spot treat by spraying areas where cyanobacteria are starting to grow. Spot treatment may be useful when wind blows the bacteria against one shoreline.

Inspect the dugout once per week after treatment. Blooms can grow and die off within a one to two week period. A dugout should not be treated with copper more than four times during one open-water season.

Appendix 4 Contacts and References

Contacts

Prairie Water News
c/o Saskatchewan Research Council
125 – 15 Innovation Boulevard
Saskatoon, Saskatchewan S7N 2X8
Phone: (306) 933-5400 Fax: (306) 933-7446
E-mail: info@src.sk.ca
Website: http://www.quantumlynx.com/water

Agriculture and Agri-Food Canada - PFRA
Headquarters
603 - 1800 Hamilton Street
Regina, Saskatchewan S4P 4L2
Phone: 1-800-667-7644 Fax: (306) 780-5018
Website: http://www.agr.ca/pfra

Alberta Agriculture, Food and Rural Development
201 J. G. O'Donoghue Building
7000 - 113 Street
Edmonton, Alberta T6H 5T6
Phone: (780) 427-2181 Fax: (780) 422-7755
Website: http://www.agric.gov.ab.ca./

Manitoba Conservation
Library Services
Suite 160, 123 Main Street,
Winnipeg, MB R3C 1A5
Phone: (204) 945-7126 Fax: (204) 948-2357
E-mail: wbarber@gov.mb.ca
Website: http://www.gov.mb.ca/conservation/publications

Manitoba Water Services Board
Intergovernmental Affairs
Province of Manitoba
2022 Currie Blvd.
PO Box 22080
Brandon, MB R7A 6Y9
Phone: 204-726-6076 Fax: 204-726-6290

Saskatchewan Health
Provincial Laboratory Environmental Sciences Section
3211 Albert Street
Regina, Saskatchewan S4S 5W6
Phone: (306) 787-3140 Fax: (306) 798-0046
Website: http://www.health.gov.sk.ca/

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Website: http://www.src.sk.ca

Sask Water
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4th Floor, Victoria Place
111 Fairford Street East
Moose Jaw, Saskatchewan S6H 7X9
Phone: (306) 694-3900 Fax: (306) 694-3944
Website: http://www.saskwater.com

Internet Health References

Health Canada has a number of different websites available on the Internet that deal specifically with water quality and human health. Relevant sites that are current at the time of publication of this document are listed below. For additional information regarding water quality issues and the impact on human health, contact your regional public health authority.

General information on drinking water quality guidelines:
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/dwguide.htm

Canadian drinking water quality guidelines (detailed summary):
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/summary.pdf

Supporting documentation for drinking water quality guidelines:
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch_pubs/dwgsup_doc/dwgsup_doc.htm

General information on water and human health:
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/97ehd215/water.pdf

General fact sheet on water:
http://www.hc-sc.gc.ca/hppb/healthyenvironment/waterfac.htm

Chlorinated water and health effects:
http://www.hc-sc.gc.ca/ehp/ehd/bch/water_quality/chlorinated_water.htm

Giardia and cryptosporidium in drinking water:
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/giardia.htm

Water treatment devices:
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/disinfection_devices.htm
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/general/iyh/water_treat/taste.htm

Questions and answers on bottled water:
http://www.hc-sc.gc.ca/food- aliment/english/organization/microbial_hazards/faqs_bottle_water_eng.html

Health Canada water quality activities:
http://www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm
http://www.hc-sc.gc.ca/english/azindex_vwxyz.htm#W

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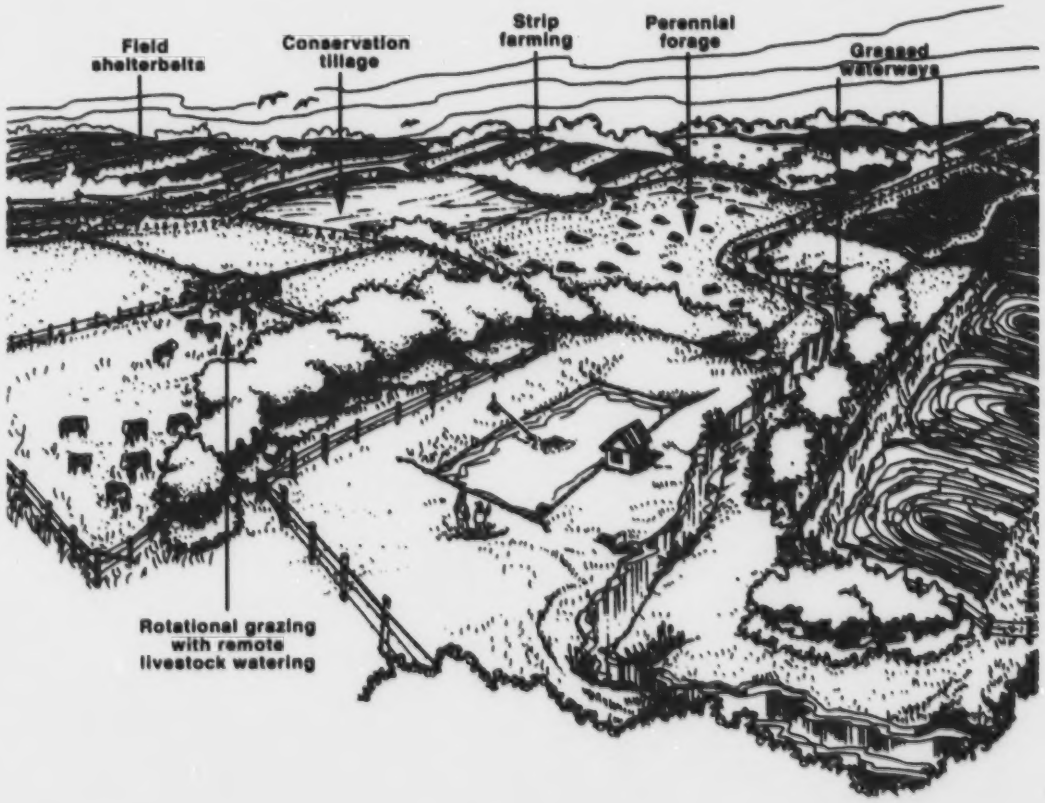
Dugout Sizing Worksheet



Joe Agricola Example

This example is provided to help you size your farm dugout and determine if the runoff area selected will supply sufficient water. A blank copy of this worksheet package is provided in the pocket inside the back cover.

Mr. Joe Agricola lives near Kindersley, Saskatchewan. He farms with his wife, son, daughter-in-law, and two grandchildren (six people in total). They currently have a 150 sow, farrow to finish hog operation and use two wells to supply water for the hogs and their two households. They also require water for their farmyard, gardens, and crop spraying. They plan to expand their farming operation to include 200 cow-calf pairs. The cattle will be at home for 7 months of the year and then moved away to summer pasture.

Joe is concerned that his existing farmyard wells may not supply sufficient water for the planned expansion. To determine this, he completed the **Annual Water Supply Inventory Worksheet** in **Step 1**. Joe calculated the total, annual water volume that could be expected from the two existing wells to be 1,226,400 gallons or 1.2 million Imperial gallons (mIg).

Joe then completed the **Annual Water Requirement Worksheet** in **Step 2**, and calculated this to be 1,773,025 gallons or 1.8 mIg. The two wells are connected into the same water system, and are currently supplying approximately 1,116,900 gallons or 1.1 mIg of this total. The household uses 131,400 gallons, and the hog operation uses 985,500 gallons annually.

In **Step 3**, Joe completed the **Sustainability of Water Sources Worksheet** and decided that his two wells are **only** sustainable to supply the existing water requirements for the two households and the hog operation resulting in a deficit of 546,625 gallons. From experience Joe knew it was extremely difficult to find a good producing well on his farm and therefore decided on a dugout to meet the remaining farm water requirements. After considering the recommendations of a water specialist, Joe decided to construct a new dugout large enough to hold a two-year supply of water. This included the losses expected from evaporation and ice tie-up.

In **Step 4**, Joe used the **Water Required From New Source Worksheet** to calculate the amount of water he will require from the new dugout. For the cattle he needed 504,000 gallons, plus 152,125 gallons for yard watering and crop spraying, for a total of 656,125 gallons or 0.7 mIg (rounded to the nearest 0.1).

From the **Evaporation Zones Map**, **Step 5**, he determined that his farm was located in Zone 4.

In **Step 6**, Joe used 0.7 million Imperial gallons from **Step 4**, for the **Required Dugout Capacity** table. This table enables the calculation of a two-year water supply, and includes the evaporation and ice tie-up factors that were explained to Joe by the water specialist. He located Zone 4 in the table and considered the options - 15,18, and 21 foot depths. He then compared the dugout capacities needed to supply 0.7 million Imperial gallons at the three depths, and easily recognized the smaller capacity of a deeper dugout. At 21 feet, the required dugout size is

2.70 mlg compared to 3.29 mlg at 18 feet, and 4.81 mlg at 15 feet. It was obvious that the construction costs would be significantly reduced with a deeper dugout, and therefore he decided on a 21 foot depth. He planned to confirm with his dugout construction contractor that this depth was possible at the proposed site.

In **Step 7**, Joe calculated the volume of earth to be excavated by converting the 2.7 mlg (2,700,000 Imperial gallons) from **Step 6** into cubic yards. He divided 2,700,000 by 169, which is the number of gallons contained in a cubic yard **(volume in Imperial gallons ÷ 169 gallons/cubic yard = cubic yards** therefore, 2,700,000 ÷ 169 = 15,976). Joe rounded it to 16,000 cubic yards for convenience.

Joe determined that by choosing to construct a 21 foot deep dugout, rather than a 15 foot deep dugout, he could save over **$12,000** in excavation costs based on a $1.00 per cubic yard estimated cost as shown below.

Dugout Depth	**15 foot**	**18 foot**	**21 foot**
Annual water requirement @ 0.7 million Imperial gallons (mlg)	4.81 mlg	3.29 mlg	2.70 mlg
Gallons to cubic yard conversion	28,461	19,467	15,976
Excavation cost @ $1.00 /cubic yard	$28,461	$19,467	$15,976
Construction Cost @ 15 foot minus 21 foot	$28,461 - $15,976 = **$12,485**		

Then in **Step 8**, Joe moves to the 21 foot depth **Dimensions and Capacity** table. Working through **Step 9**, Joe chose a 100 foot width. In **Step 10**, he moved down the table to find the closest capacity to 16,000 cubic yards as shown. In **Step 11**, he reads to the far left column to obtain the required length of dugout. The length required for a 21 foot deep, dugout with 1.5:1 end and side slopes was between 320 and 340 feet, and therefore 330 feet was chosen.

Joe located his farm on the **Runoff Map** in **Step 12**, to find that it required between 250 and 500 acres to fill a one million Imperial gallon dugout. To be safe he selected the higher end of the range at 500 acres.

In **Step 13**, he multiplied 500 acres by 2.7 million gallons to determine the size of the runoff area required for his dugout **(500 acres x 2.7 = 1,350 acres)**.

There appeared to be a good dugout location within 500 feet of the farmyard. With his calculated information in hand, and a local topography map, Joe set off on a field trip to determine local runoff patterns and confirm the location for the proposed dugout. At the site, 500 feet from his buildings, there was approximately **1,000** acres of runoff area, which was less than the **1,350** acres his dugout required. For this reason, he selected another site 500 feet further downstream where a second waterway contributes another 500 acres of runoff area. Joe considered the additional runoff water was well worth the costs for 500 feet of additional trenching and piping.

Note: For additional information on dugout and runoff area sizing contact a water specialist in your area.

Dugout Sizing Worksheets

Completing this exercise can potentially save you thousands of dollars in construction costs. It is designed to enable producers to size their farm dugout, and determine if the runoff area will supply sufficient water to the dugout. The following tables and calculations are based on the assumption that all four sides of the dugout have a slope ratio of **1.5:1**. If it is not possible to excavate to these specifications, contact a local water specialist for assistance.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Annual Water Supply Inventory**	1.2 million Imperial gallons (mIg)
Step 2	**Annual Water Requirement**	1.8 million Imperial gallons (mIg)
Step 3	**Sustainability of Water Sources**	____ Yes, or ✓ No
Step 4	**Water Required From New Source**	0.7 million Imperial gallons (mIg)
Step 5	**Evaporation Zone Number**	4
Step 6	**Dugout Capacity**	2.7 million Imperial gallons (mIg)
Step 7	**Volume of Excavation**	16,000 cubic yards
Step 8	**Dugout Depth**	21 feet
Step 9	**Dugout Width**	100 feet
Step 10	**No Data Recorded**	
Step 11	**Dugout Length**	330 feet
Step 12	**Runoff Area Required**	500 acres/mIg
Step 13	**Total Runoff Area Required**	1,350 acres

Store your completed information in the pocket at the back of this manual.

STEPS TO SIZE YOUR DUGOUT

Step 1 Complete the **Annual Water Supply Inventory Worksheet**, and calculate the total volume of water available from all existing farm and non-farm sources for the purpose intended – wells, other dugouts, pipelines, canals, springs, rivers, and hauling, etc. To calculate the Expected Annual Volume Supplied by each well, multiply its well production in gpm x 8 hours per day x 60 minutes per hour x 365 days per year. For existing dugouts and other sources determine the expected annual volume supplied, based on past use and experience with these sources. The table provided in **Step 2** can be used to calculate the water requirements for various farm uses. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 2 Estimate the volume of water required from the dugout by using the **Annual Water Requirement Worksheet**, and fill in accurate data for your existing operation or planned expansion. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 3 Complete the **Sustainability of Water Sources Worksheet** provided to determine if the supply, construction materials, and water quality will last. Start by subtracting the Annual Water Supply Inventory in **Step 1**, from the Annual Water Requirement in **Step 2** to determine either a water surplus or deficit. Based on all your responses in the worksheet are your sources sustainable?

Step 4 Complete the **Water Required From New Source Worksheet** by totalling only the water uses you plan to supply from this new water source. Use the totals or subtotals you calculated for the various farm water uses in **Step 1**. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 5 Determine your Evaporation Zone number by locating your farm on the **Evaporation Zones Map**.

Step 6 Use the **Required Dugout Capacity** table for this step. Locate the **Water Required From New Source** as determined in **Step 4**, in the first column of the **Required Dugout Capacity** table. Then read across to your Evaporation Zone number as determined in **Step 5**, and choose either a **15**, **18**, or **21** foot dugout depth. The figure in the chosen column represents the necessary Dugout Capacity in millions of Imperial gallons. It is important to understand that this number designates the recommended **two-year supply of water, and allows for evaporation losses and ice.**

Step 7 Multiply the Dugout Capacity determined in **Step 6** by **1,000,000** to convert it to gallons and then divide by **169**, which is the number of Imperial gallons in a cubic yard. The resulting number is the Volume of Earth to be Excavated.

Step 8 From the **Dimensions and Capacity** tables, select the Dugout Depth chart you have chosen in **Step 6** (15, 18, or 21 foot chart).

Step 9 Using the chosen Dugout Depth chart from **Step 8**, select the desired Dugout Width from the top row of the table. As a rule of thumb for dugouts with a side slope ratio of **1.5:1**, **the width should be at least four times the depth.** This is a good starting point, although further adjustment may be required to include factors created by topography, road setbacks, water courses, and construction equipment. **Steps 9** and **10** may have to be repeated to finalize your dimensions.

Step 10 From your selected Dugout Width in **Step 9**, read down to find the required volume in cubic yards as determined in **Step 7**.

Step 11 From the volume number selected in **Step 10**, read back across to the far, left-hand column to obtain the required length of the dugout.

> **Note: Now that you have sized the dugout (length, width, depth, and capacity), you need to determine if the runoff area will supply sufficient water to the dugout.**

Step 12 Locate your farm on the **Runoff Map**. This map allows you to determine the number of acres of land area required to collect each million Imperial gallons of dugout capacity. Acres required is given as a range of values as indicated in the legend to the left of the map. Use an average value of the range in your calculation or use the higher value for increased confidence.

Step 13 Multiply the Number of Acres Required determined in **Step 12**, by the Dugout Capacity Required in millions of Imperial gallons as determined in **Step 6**. The resulting number is the total Runoff Area for the dugout.

> **Note: The calculated runoff acreage or watershed obtained in Step 13 represents the land area needed to supply sufficient water to this dugout. A field trip will be needed to confirm that the dugout site or sites you have chosen actually receive the expected runoff. If a particular watershed is too small to provide enough water, you have three choices:**
>
> - **Find another watershed.**
> - **Find an additional watershed and build a second dugout.**
> - **Find another water source.**
>
> **For further assistance on dugout and watershed sizing, contact a local water specialist.**

Step 1 Annual Water Supply Inventory Worksheet

Existing Wells

Purpose	Land Location	Date Constructed	Depth (feet)	Casing Diameter (inches)	Well Production (gal/min)	Expected Annual Volume Supplied (gal)
1. *House*	*home 1/4*	*1990*	*110*	*6*	*1.5*	*262,800*
2. *Hogs*	*home 1/4*	*1995*	*220*	*6*	*5.5*	*963,600*
3.						
					Well Subtotal A	*1,226,400*

Existing Dugouts

Purpose	Land Location	Date Constructed	Length (feet)	Width (feet)	Depth (feet)	Capacity (million Imperial gallons)	Expected Annual Volume Supplied (gal)
1.							
2.							
3.							
						Dugout Subtotal B	

Other Existing Water Sources and Their Limitations (springs, creeks, rivers, and hauling etc.)

1.	
2.	
3.	
	Other Subtotal C

Annual Water Supply Inventory Total (A+B+C) = *1,226,400* gallons

Annual Water Supply Inventory = *1,226,400* gallons / 1,000,000 = *1.2* (nearest 0.1) million Imperial gallons

Step 1 Annual Water Supply Inventory Worksheet

Existing Wells

Purpose	Land Location	Date Constructed	Depth (feet)	Casing Diameter (inches)	Well Production (gal/min)	Expected Annual Volume Supplied (gal)
1. *House*	*home 1/4*	*1990*	*110*	*6*	*1.5*	*262,800*
2. *Hogs*	*home 1/4*	*1995*	*220*	*6*	*5.5*	*963,600*
3.						
					Well Subtotal A	*1,226,400*

Existing Dugouts

Purpose	Land Location	Date Constructed	Length (feet)	Width (feet)	Depth (feet)	Capacity (million Imperial gallons)	Expected Annual Volume Supplied (gal)
1.							
2.							
3.							
						Dugout Subtotal B	

Other Existing Water Sources and Their Limitations (springs, creeks, rivers, and hauling etc.)

1.	
2.	
3.	
Other Subtotal C	

Annual Water Supply Inventory Total (A+B+C) = *1,226,400* gallons

Annual Water Supply Inventory = *1,226,400* gallons / 1,000,000 = *1.2* (nearest 0.1) **million Imperial gallons**

Step 2 Annual Water Requirement Worksheet

This worksheet can be used to estimate the total annual farm water requirement, and assist producers in sizing farm dugouts. The water requirements are based on typical average outside or in-barn temperatures experienced throughout the year. Livestock water consumption is much higher on hot summer days and pumping capacity requirements must be considered when designing farm water systems.

Household Use	No. of People		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
People	6	x	60.0 gpd	x 365	= 131,400	= 131,400

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
Beef							
Feeder (on silage)	550 lb.		x	4.0 gpd	x	=	
	900 lb.		x	7.0 gpd	x	=	
	1250 lb.		x	10.0 gpd	x	=	
Cows with Calves	1300 lb.	200	x	12.0 gpd	x 210	= 504,000	
Dry Cow (on pasture or hay)	1300 lb.		x	10.0 gpd	x	=	
Calves	250 lb.		x	2.0 gpd	x	=	
					Sub Total A gallons per year	504,000	
Swine							
Farrow to Finish		150	x	18.0 gpd	x 365	= 985,500	
Farrow to Late Wean	50 lb.		x	6.5 gpd	x	=	
Farrow to Early Wean	15 lb.		x	5.5 gpd	x	=	
Feeder	50-250 lb.		x	1.5 gpd	x	=	
Weaner	15-50 lb.		x	0.5 gpd	x	=	
					Sub Total B gallons per year	985,500	

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Total
Dairy							
Milking Cow **	Holstein	_____	x	30.0 gpd	x _____	= _____	
Dry Cows/Replacemnn Heifer	Holstein	_____	x	10.0 gpd	x _____	= _____	
Calves	600 lb.	_____	x	5.0 gpd	x _____	= _____	
** includes 3 gpd/cow for wash water					Sub Total C gallons per year	_____	
Poultry							
Broilers		_____	x	0.035 gpd	x _____	= _____	
Roosters/Pullets		_____	x	0.040 gpd	x _____	= _____	
Layers		_____	x	0.055 gpd	x _____	= _____	
Breeders		_____	x	0.070 gpd	x _____	= _____	
Turkey Growers		_____	x	0.130 gpd	x _____	= _____	
Turkey Heavies		_____	x	0.160 gpd	x _____	= _____	
					Sub Total D gallons per year	_____	
Sheep/Goats/Horses							
Ewes/Does		_____	x	2.0 gpd	x _____	= _____	
Milking Ewes/Does		_____	x	3.0 gpd	x _____	= _____	
Horses		_____	x	11.0 gpd	x _____	= _____	
					Sub Total E gallons per year	_____	
					Livestock Total (A+B+C+D+E) gallons per year	= *1,489,500*	= *1,489,500*

Other Water Uses						Total
Irrigation of garden and yard use in the summer (assume 6 in. application)						
Irrigated area (sq ft)	0.5 ft x *43,560* sq ft	x	6.25 gal/ft³	= *136,125* gal		
Chemical spraying (acres)	10 gal/acre	x	*1600* acres	= *16,000* gal		
Greenhouse				= _____ gal		
Fire (1200 gal/2 hour period)				= _____ gal		
			Other Water Use Total gallons per year	= *152,125*		= *152,125*

Annual Water Requirement Total	= *1,773,025* gallons	Annual Water Requirement	= *1,773,025* gallons / 1,000,000	= *1.8* (nearest 0.1)	million Imperial gallons

Step 2 Annual Water Requirement Worksheet

This worksheet can be used to estimate the total annual farm water requirement, and assist producers in sizing farm dugouts. The water requirements are based on typical average outside or in-barn temperatures experienced throughout the year. Livestock water consumption is much higher on hot summer days and pumping capacity requirements must be considered when designing farm water systems.

Household Use		No. of People		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
People		6	x	60.0 gpd	x 365	= 131,400	= 131,400

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
Beef							
Feeder (on silage)	550 lb.		x	4.0 gpd	x	=	
	900 lb.		x	7.0 gpd	x	=	
	1250 lb.		x	10.0 gpd	x	=	
Cows with Calves	1300 lb.	200	x	12.0 gpd	x 210	= 504,000	
Dry Cow (on pasture or hay)	1300 lb.		x	10.0 gpd	x	=	
Calves	250 lb.		x	2.0 gpd	x	=	
					Sub Total A gallons per year	504,000	
Swine							
Farrow to Finish		150	x	18.0 gpd	x 365	= 985,500	
Farrow to Late Wean	50 lb.		x	6.5 gpd	x	=	
Farrow to Early Wean	15 lb.		x	5.5 gpd	x	=	
Feeder	50-250 lb.		x	1.5 gpd	x	=	
Weaner	15-50 lb.		x	0.5 gpd	x	=	
					Sub Total B gallons per year	985,500	

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Total
Dairy							
Milking Cow **	Holstein	_____	x	30.0 gpd	x _____	= _____	
Dry Cows/Replacemen Heifer	Holstein	_____	x	10.0 gpd	x _____	= _____	
Calves	600 lb.	_____	x	5.0 gpd	x _____	= _____	
** includes 3 gpd/cow for wash water					**Sub Total C** gallons per year		
Poultry							
Broilers		_____	x	0.035 gpd	x _____	= _____	
Roasters/Pullets		_____	x	0.040 gpd	x _____	= _____	
Layers		_____	x	0.055 gpd	x _____	= _____	
Breeders		_____	x	0.070 gpd	x _____	= _____	
Turkey Growers		_____	x	0.130 gpd	x _____	= _____	
Turkey Heavies		_____	x	0.160 gpd	x _____	= _____	
					Sub Total D gallons per year	_____	
Sheep/Goats/Horses							
Ewes/Does		_____	x	2.0 gpd	x _____	= _____	
Milking Ewes/Does		_____	x	3.0 gpd	x _____	= _____	
Horses		_____	x	11.0 gpd	x _____	= _____	
					Sub Total E gallons per year	_____	
					Livestock Total (A+B+C+D+E) gallons per year	= 1,489,500	= 1,489,500

Other Water Uses						Total
Irrigation of garden and yard use in the summer (assume 6 in. application)						
Irrigated area (sq ft)	0.5 ft x 43,560 sq ftx	x	6.25 gal/ft²	= 136,125 gal		
Chemical spraying (acres)	10 gal/acre	x	1600 acres	= 16,000 gal		
Greenhouse				= _____ gal		
Fire (1200 gal/2 hour period)				= _____ gal		
			Other Water Use Total gallons per year	= 152,125		= 152,125

Annual Water Requirement Total	= 1,773,025 gallons	**Annual Water Requirement**	= 1,773,025 gallons / 1,000,000	= 1.8 (nearest 0.1)	million Imperial gallons

Step 3 Sustainability of Water Sources Worksheet

(a) To determine if the supply is sustainable:

1,226,400 gallons	-	1,773,025 gallons	=	- 546,625 gallons
Annual Water Supply Inventory (Step 1)		Annual Water Requirement (Step 2)		Water Surplus or deficit

For wells:

Is your groundwater supply depleting, as indicated by a steady drop in non-pumping water levels over a period of months or years? ____ Yes, or ✓ No

For dugouts:

Is the water level in your dugout(s) continuing to drop over a period of years? ____ Yes, or ____ No

Has your dugout(s) lost considerable volume and depth due to sediment deposition? ____ Yes, or ____ No

For other sources:

Are these sources sustainable? ____ Yes, or ____ No

(b) To determine if the construction materials will last:

For wells:

Does your well(s) have metal casing and/or liner? The life expectancy of this is about 20 years. ____ Yes, or ✓ No

Do you notice more sediment being pumped from your well(s)? This can result from rusted well casing or liner. ____ Yes, or ✓ No

(c) To determine if the water quality is sustainable:

Is it becoming increasingly difficult to maintain the water quality in your well or dugout by regular maintenance treatments such as shock chlorination for well(s) and algae and weed control in your dugout(s)? ____ Yes, or ✓ No

Based on your previous experience with your water sources and your responses to (a), (b), and (c), in your opinion are your existing water sources sustainable for the next 5 year period?

____ Yes (No new water source is required - stop here!)

✓ No (A new water source is required, go to Step 4)

Step 4 Water Required From New Source Worksheet

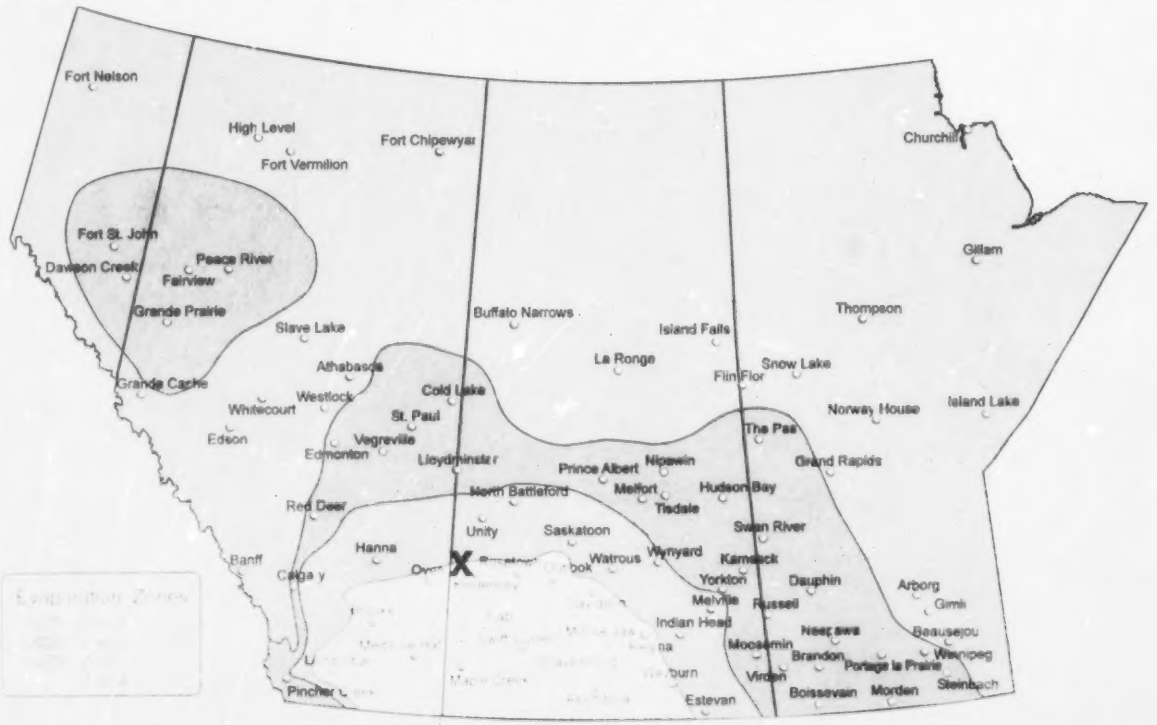
Add together only the water uses to be supplied from this new water source.

_____	gallons	+	*504,000*	gallons	+	*152,125*	gallons	=	*656,125*	gallons
Household Use			Livestock Use Subtotal or Total			Other Water Uses			Water Required From New Source	

Convert gallons to million Imperial gallons: *656,125* gallons (Water Required From New Source) ÷ 1,000,000 = *0.7* mlg (nearest 0.1)

—

Step 5 Evaporation Zones Map



Step 6 Required Dugout Capacity (millions of Imperial gallons)

Additional Annual Water Required	Zone 1			Zone 2			Zone 3			Zone 4		
	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet
0.20	0.79	0.65	0.58	0.94	0.73	0.64	1.08	0.81	0.70	1.35	0.94	0.78
0.25	1.00	0.81	0.73	1.19	0.92	0.80	1.35	1.01	0.87	1.69	1.17	0.97
0.30	1.21	0.98	0.87	1.43	1.10	0.96	1.63	1.21	1.04	2.04	1.40	1.16
0.35	1.42	1.15	1.02	1.68	1.29	1.12	1.91	1.42	1.21	2.38	1.64	1.35
0.40	1.63	1.32	1.17	1.93	1.49	1.28	2.19	1.63	1.38	2.73	1.87	1.54
0.45	1.84	1.49	1.32	2.18	1.68	1.45	2.46	1.83	1.56	3.07	2.11	1.74
0.50	2.06	1.67	1.47	2.43	1.87	1.61	2.74	2.04	1.73	3.42	2.35	1.93
0.60	2.48	2.01	1.77	2.93	2.25	1.94	3.30	2.46	2.08	4.11	2.82	2.32
0.70	2.91	2.36	2.08	3.43	2.64	2.27	3.87	2.87	2.44	4.81	3.29	2.70
0.80	3.34	2.71	2.39	3.93	3.03	2.61	4.43	3.29	2.79	5.50	3.77	3.09
0.90	3.77	3.05	2.69	4.43	3.42	2.94	4.99	3.71	3.14	6.20	4.25	3.48
1.00	4.20	3.40	3.00	4.94	3.81	3.27	5.56	4.13	3.50	6.90	4.73	3.87
1.20	5.06	4.11	3.62	5.95	4.59	3.94	6.69	4.97	4.21	8.29	5.68	4.65
1.40	5.92	4.81	4.24	6.97	5.37	4.62	7.82	5.81	4.92	9.69	6.64	5.43
1.60	6.79	5.52	4.86	7.98	6.16	5.29	8.96	6.66	5.63	11.09	7.60	6.22
1.80	7.66	6.22	5.49	9.00	6.94	5.97	10.09	7.50	6.35	12.49	8.56	7.00
2.00	8.53	6.93	6.11	10.02	7.73	6.65	11.23	8.35	7.07	13.90	9.53	7.79
2.20	9.36	7.61	6.72	11.00	8.49	7.30	12.32	9.17	7.76	15.24	10.45	8.54

Note: The shallower the dugout the larger its surface dimensions must be. A larger surface area produces increased losses to evaporation and water tied up as ice and unavailable during the winter. In Zone 4, for example the surface dimensions of a 15 foot deep, dugout must be 45 percent larger than an 18 foot deep, dugout and 80 percent larger than a 21 foot, deep dugout.

Step 7 Volume of Excavation (cubic yards)

Dugout Capacity (Step 6)							Volume of Earth to be Excavated		
2.7	x 1,000,000	=	*2,700,000*	÷	169	=	*15,976*	=	*16,000*
mlg			gallons		(gal cubic yard)				round to nearest 100 cubic yards

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 15 Foot Depth

Width (feet)	50	60	70	80	90	100	110	120
Length (feet)								
60	700	900						
80	1000	1300	1600	1900				
100	1300	1700	2100	2600	3000	3400		
120	1600	2100	2700	3200	3800	4300	4800	5400
140	1900	2500	3200	3800	4500	5200	5800	6500
160	2200	3000	3700	4500	5300	6000	6800	7500
180	2500	3400	4300	5100	6000	6900	7800	8600
200	2800	3800	4800	5800	6800	7700	8700	9700
220	3100	4200	5300	6400	7500	8600	9700	10800
240	3400	4600	5800	7000	8300	9500	10700	11900
260	3700	5000	6400	7700	9000	10300	11600	13000
280	4000	5500	6900	8300	9800	11200	12600	14000
300	4300	5900	7400	9000	10500	12000	13600	15100
320	4600	6300	7900	9600	11300	12900	14600	16200
340	4900	6700	8500	10200	12000	13800	15500	17300
360	5300	7100	9000	10900	12800	14600	16500	18400
380	5600	7500	9500	11500	13500	15500	17500	19500
400	5900	8000	10100	12200	14300	16300	18400	20500
420	6200	8400	10600	12800	15000	17200	19400	21600
440	6500	8800	11100	13400	15800	18100	20400	22700
460	6800	9200	11600	14100	16500	18900	21400	23800

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 6 Required Dugout Capacity (millions of Imperial gallons)

Additional Annual Water Required	Zone 1			Zone 2			Zone 3			Zone 4		
	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity) for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet
0.20	**0.79**	**0.65**	**0.58**	**0.94**	**0.73**	**0.64**	**1.08**	**0.81**	**0.70**	**1.35**	**0.94**	**0.78**
0.25	1.00	0.81	0.73	1.19	0.92	0.80	1.35	1.01	0.87	1.69	1.17	0.97
0.30	**1.21**	**0.98**	**0.87**	**1.43**	**1.10**	**0.96**	**1.63**	**1.21**	**1.04**	**2.04**	**1.40**	**1.16**
0.35	1.42	1.15	1.02	1.68	1.29	1.12	1.91	1.42	1.21	2.38	1.64	1.35
0.40	**1.63**	**1.32**	**1.17**	**1.93**	**1.49**	**1.28**	**2.19**	**1.63**	**1.38**	**2.73**	**1.87**	**1.54**
0.45	1.84	1.49	1.32	2.18	1.68	1.45	2.46	1.83	1.56	3.07	2.11	1.74
0.50	**2.06**	**1.67**	**1.47**	**2.43**	**1.87**	**1.61**	**2.74**	**2.04**	**1.73**	**3.42**	**2.35**	**1.93**
0.60	2.48	2.01	1.77	2.93	2.25	1.94	3.30	2.46	2.08	4.11	2.82	2.32
0.70	**2.91**	**2.36**	**2.08**	**3.43**	**2.64**	**2.27**	**3.87**	**2.87**	**2.44**	**4.81**	**3.29**	**2.70**
0.80	3.34	2.71	2.39	3.93	3.03	2.61	4.43	3.29	2.79	5.50	3.77	3.09
0.90	**3.77**	**3.05**	**2.69**	**4.43**	**3.42**	**2.94**	**4.99**	**3.71**	**3.14**	**6.20**	**4.25**	**3.48**
1.00	4.20	3.40	3.00	4.94	3.81	3.27	5.56	4.13	3.50	6.90	4.73	3.87
1.20	**5.06**	**4.11**	**3.62**	**5.95**	**4.59**	**3.94**	**6.69**	**4.97**	**4.21**	**8.29**	**5.68**	**4.65**
1.40	5.92	4.81	4.24	6.97	5.37	4.62	7.82	5.81	4.92	9.69	6.64	5.43
1.60	**6.79**	**5.52**	**4.86**	**7.98**	**6.16**	**5.29**	**8.96**	**6.66**	**5.63**	**11.09**	**7.60**	**6.22**
1.80	7.66	6.22	5.49	9.00	6.94	5.97	10.09	7.50	6.35	12.49	8.56	7.00
2.00	**8.53**	**6.93**	**6.11**	**10.02**	**7.73**	**6.65**	**11.23**	**8.35**	**7.07**	**13.90**	**9.53**	**7.79**
2.20	9.36	7.61	6.72	11.00	8.49	7.30	12.32	9.17	7.76	15.24	10.45	8.54

Note: The shallower the dugout the larger its surface dimensions must be. A larger surface area produces increased losses to evaporation and water tied up as ice and unavailable during the winter. In Zone 4, for example the surface dimensions of a 15 foot deep, dugout must be 45 percent larger than an 18 foot deep, dugout and 80 percent larger than a 21 foot, deep dugout.

Step 7 Volume of Excavation (cubic yards)

Dugout Capacity (Step 6)								
	2.7	x 1,000,000 =	2,700,000	÷ 169 =	Volume of Earth to be Excavated	15,976 -	16,000
	mlg		gallons	(gal/cubic yard)		round to nearest 100 cubic yards	

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 15 Foot Depth

Width (feet)	50	60	70	80	90	100	110	120
Length (feet)								
60	700	900						
80	1000	1300	1600	1900				
100	1300	1700	2100	2600	3000	3400		
120	1600	2100	2700	3200	3800	4300	4800	5400
140	1900	2500	3200	3800	4500	5200	5800	6500
160	2200	3000	3700	4500	5300	6000	6800	7500
180	2500	3400	4300	5100	6000	6900	7800	8600
200	2800	3800	4800	5800	6800	7700	8700	9700
220	3100	4200	5300	6400	7500	8600	9700	10800
240	3400	4600	5800	7000	8300	9500	10700	11900
260	3700	5000	6400	7700	9000	10300	11600	13000
280	4000	5500	6900	8300	9800	11200	12600	14000
300	4300	5900	7400	9000	10500	12000	13600	15100
320	4600	6300	7900	9600	11300	12900	14600	16200
340	4900	6700	8500	10200	12000	13800	15500	17300
360	5300	7100	9000	10900	12800	14600	16500	18400
380	5600	7500	9500	11500	13500	15500	17500	19500
400	5900	8000	10100	12200	14300	16300	18400	20500
420	6200	8400	10600	12800	15000	17200	19400	21600
440	6500	8800	11100	13400	15800	18100	20400	22700
460	6800	9200	11600	14100	16500	18900	21400	23800

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 18 Foot Depth

Width (feet)	60	70	80	90	100	110	120	130
Length (feet)								
60	900							
80	1300	1700	2000					
100	1800	2300	2700	3200	3700			
120	2200	2800	3400	4100	4700	5300	5900	
140	2600	3400	4200	4900	5700	6400	7200	7900
160	3100	4000	4900	5700	6600	7500	8400	9300
180	3500	4500	5600	6600	7600	8600	9600	10700
200	4000	5100	6300	7400	8600	9700	10900	12000
220	4400	5700	7000	8300	9600	10800	12100	13400
240	4800	6300	7700	9100	10500	11900	13400	14800
260	5300	6800	8400	9900	11500	13100	14800	16200
280	5700	7400	9100	10800	12500	14200	15800	17500
300	6200	8000	9800	11600	13400	15300	17100	18900
320	6600	8600	10500	12500	14400	16400	18300	20300
340	7000	9100	11200	13300	15400	17500	19600	21700
360	7500	9700	11900	14100	16400	18600	20800	23000
380	7900	10300	12600	15000	17300	19700	22000	24400
400	8400	10900	13300	15800	18300	20800	23300	25800
420	8800	11400	14000	16700	19300	21900	24500	27100
440	9200	12000	14800	17500	20300	23000	25800	28500
460	9700	12600	15500	18300	21200	24100	27000	29900

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Step 8

Chart for 21 Foot Depth

Step 9

Step 11

Step 10

Width (feet)	70	80	90	100	110	120	130	140
Length (feet)								
80	1700	2100	2500					
100	2300	2800	3400	3900	4400			
120	2900	3600	4300	5000	5700	6300	7000	
140	3500	4400	5200	6000	6900	7700	8600	9400
160	4100	5100	6100	7100	8100	9100	10100	11100
180	4700	5900	7000	8200	9300	10500	11600	12800
200	5300	6600	7900	9200	10500	11900	13200	14500
220	5900	7400	8800	10300	11800	13200	14700	16200
240	6500	8100	9700	11400	13000	14600	16200	17900
260	7100	8900	10700	12400	14200	16000	17800	19500
280	7700	9600	11600	13500	15400	17400	19300	21200
300	8300	10400	12500	14600	16700	18700	20800	22900
320	8900	11100	13400	15600	17800	20100	22400	24600
340	9500	11900	14300	16700	19100	21500	23900	26300
360	10100	12600	15200	17800	20300	22900	25400	28000
380	10700	13400	16100	18800	21500	24200	27000	29700
400	11300	14200	17000	19900	22800	25600	28500	31400
420	11900	14900	17900	21000	24000	27000	30000	33000
440	12500	15700	18800	22000	25200	28400	31600	34700
460	13100	16400	19800	23100	26400	29800	33100	36400
480	13700	17200	20700	24200	27600	31100	34600	38100

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 18 Foot Depth

Width (feet)	60	70	80	90	100	110	120	130
Length (feet)								
60	900							
80	1300	1700	2000					
100	1800	2300	2700	3200	3700			
120	2200	2800	3400	4100	4700	5300	5900	
140	2600	3400	4200	4900	5700	6400	7200	7900
160	3100	4000	4900	5700	6600	7500	8400	9300
180	3500	4500	5600	6600	7600	8600	9600	10700
200	4000	5100	6300	7400	8600	9700	10900	12000
220	4400	5700	7000	8300	9600	10800	12100	13400
240	4800	6300	7700	9100	10500	11900	13400	14800
260	5300	6800	8400	9900	11500	13100	14600	16200
280	5700	7400	9100	10800	12500	14200	15800	17500
300	6200	8000	9800	11600	13400	15300	17100	18900
320	6600	8600	10500	12500	14400	16400	18300	20300
340	7000	9100	11200	13300	15400	17500	19600	21700
360	7500	9700	11900	14100	16400	18600	20800	23000
380	7900	10300	12600	15000	17300	19700	22000	24400
400	8400	10900	13300	15800	18300	20800	23300	25800
420	8800	11400	14000	16700	19300	21900	24500	27100
440	9200	12000	14800	17500	20300	23000	25800	28500
460	9700	12600	15500	18300	21200	24100	27000	29900

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Step 8

Chart for 21 Foot Depth

Width (feet)	70	80	90	100	110	120	130	140
Length (feet)								
80	1700	2100	2500					
100	2300	2800	3400	3900	4400			
120	2900	3600	4300	5000	5700	6300	7000	
140	3500	4400	5200	6000	6900	7700	8600	9400
160	4100	5100	6100	7100	8100	9100	10100	11100
180	4700	5900	7000	8200	9300	10500	11600	12800
200	5300	6600	7900	9200	10500	11900	13200	14500
220	5900	7400	8800	10300	11800	13200	14700	16200
240	6500	8100	9700	11400	13000	14600	16200	17900
260	7100	8900	10700	12400	14200	16000	17800	19500
280	7700	9600	11600	13500	15400	17400	19300	21200
300	8300	10400	12500	14600	16700	18700	20800	22900
320	8900	11100	13400	15600	17900	20100	22400	24600
340	9500	11900	14300	16700	19100	21500	23900	26300
360	10100	12600	15200	17800	20300	22900	25400	28000
380	10700	13400	16100	18800	21500	24200	27000	29700
400	11300	14200	17000	19900	22800	25600	28500	31400
420	11900	14900	17900	21000	24000	27000	30000	33000
440	12500	15700	18800	22000	25200	28400	31600	34700
460	13100	16400	19800	23100	26400	29800	33100	36400
480	13700	17200	20700	24200	27600	31100	34600	38100

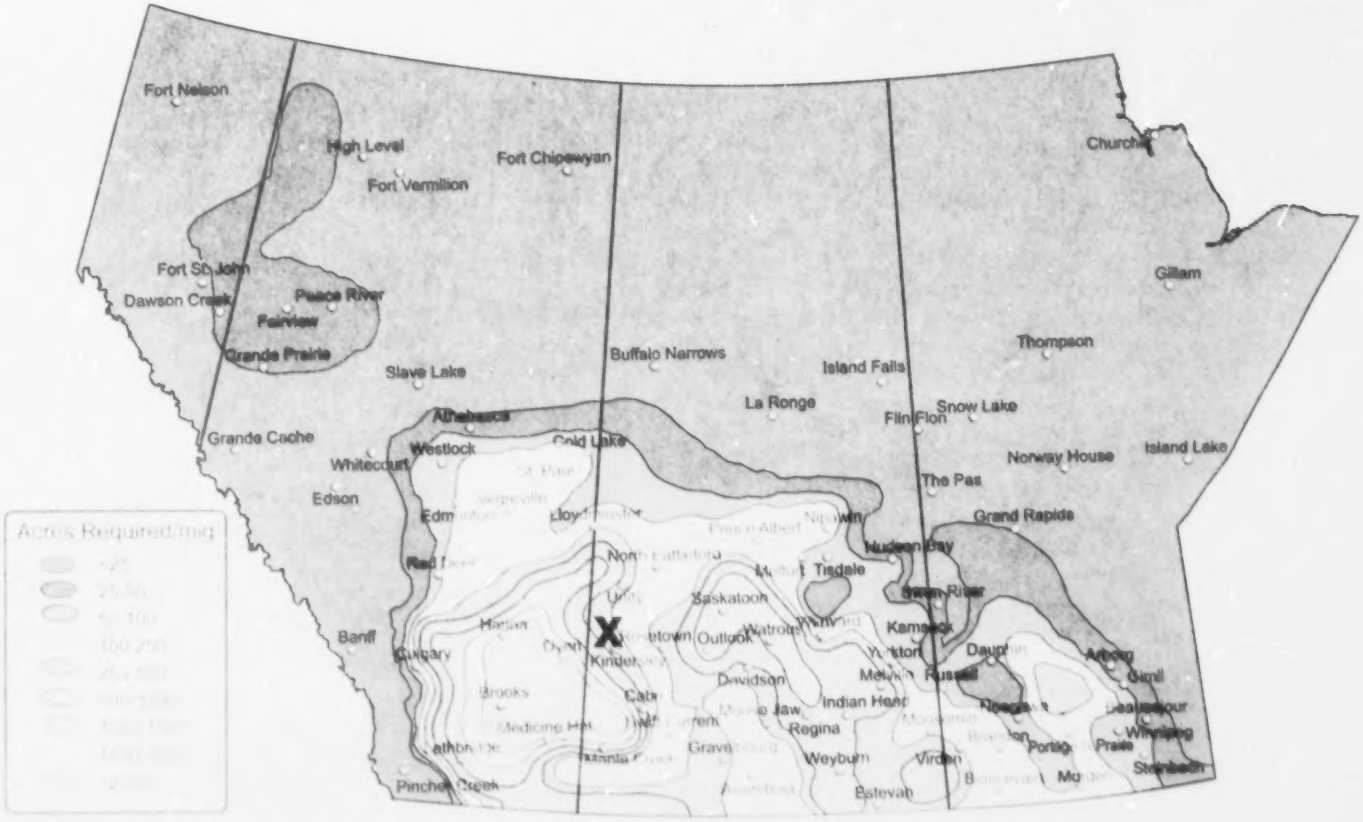
Step 9

Step 10

Step 11

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

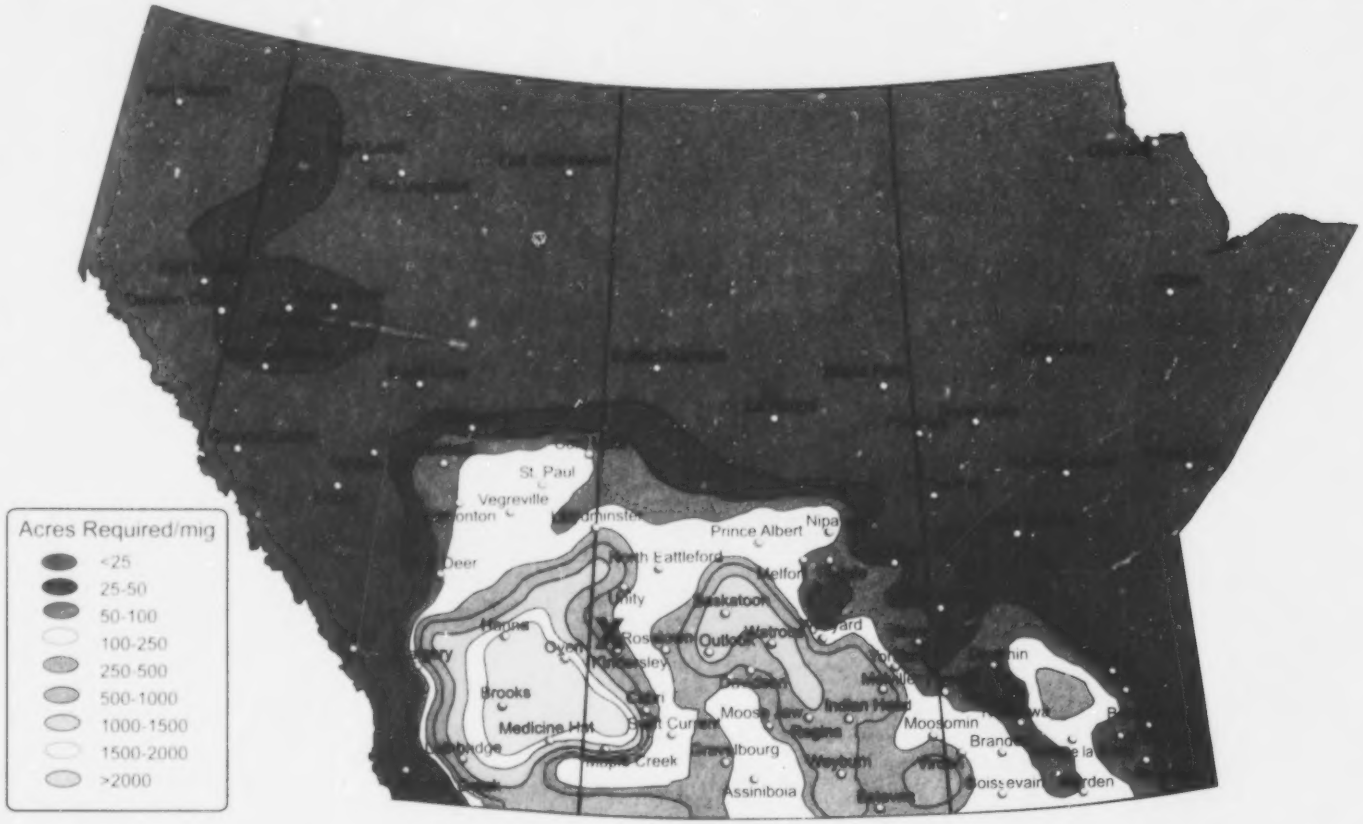
Step 12 — Runoff Map



Step 13 — Runoff Area

Number of Acres Required (Step 12)	500	x	Dugout Capacity Required	2.7	Runoff Area	1,350

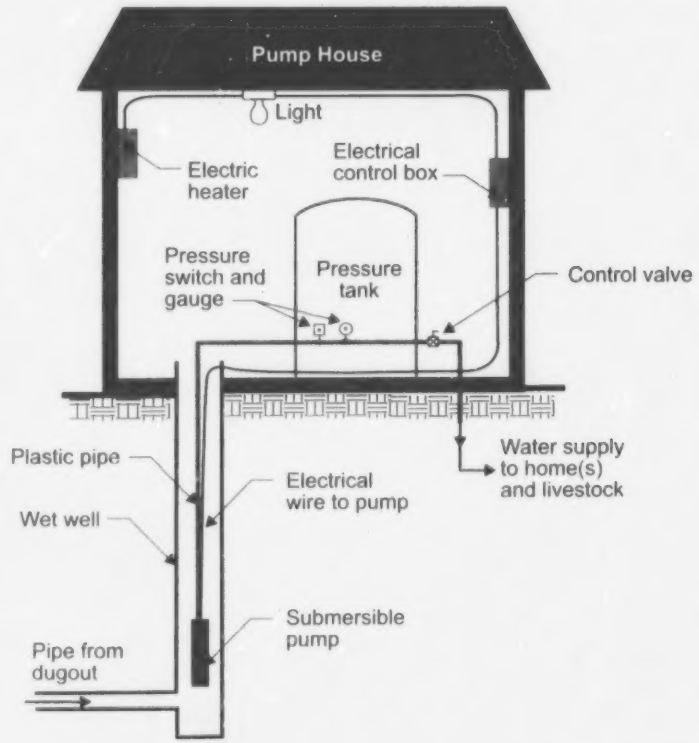
Step 12 Runoff Map



Step 13 Runoff Area

Number of Acres Required (Step 12)	500 acres required/mlg	x	Dugout Capacity Required	2.7 mlg	=	Runoff Area	1,350 acres

Water System Sizing Worksheet



Joe Agricola Example

This example is provided to help you size the pump, pressure tank, and water distribution piping for your dugout water system. It contains a written explanation of the process and completed worksheets for the Joe Agricola farm. A blank **Water System Sizing Worksheet** is provided in the pocket inside the back cover to assist you with this task.

In the **Dugout Sizing Example** found in the front pocket of the manual, we learned that Joe Agricola required dugout water for his 200 head of beef cattle, chemical spraying, plus yard use and garden irrigation. He also wants to size the dugout water system to provide fire protection, and act as a back-up supply for his hog operation should one of his wells or well pumps fail.

Beginning with **Step 1**, Joe lists all the water system fixtures he plans to supply from the dugout.

In **Step 2**, Joe considers the following to determine the required pump size and flow rate:

- What water uses are likely to occur at the same time?
  Most likely cattle and hog watering (10 + 10 = 20 Imperial gpm).
- He also wants to be able to fill a 1,000 gallon tank for chemical spraying in a hour
  (1,000 gallons ÷ 60 minutes = 17 Imperial gpm).
- The pump capacity must be at least equal to the peak use of the fixtures that use the largest amount of water.

Joe decides on 20 Imperial gallons per minute to meet the above considerations, and in **Step 3**, completes the conversion of 20 Imperial gpm to 24 U.S. gpm. This is necessary because most pumps available in Canada are sized in U.S. gpm.

To complete **Step 4**, Joe contacts a reputable, pump supplier, and is asked how much **lift** there is from the dugout to the farmyard and what pressure he requires from the water system. Joe informs him that the lift or elevation is 21 feet (lift = the dugout depth + farmyard elevation above the dugout). The dugout depth + 10 feet of additional elevation to the farmstead totals 31 feet. Joe also advises that the water system will operate between 30 and 50 psi, and so the average **pressure** required is 40 psi.

The pump supplier advises him that a one horsepower, submersible pump will do the job.

The purpose of **Step 5** is to size the **pressure tank**. As indicated in **Step 2**, Joe has determined that he needs a pump capable of delivering 24 U.S. gpm. When selecting a pressure tank, the rule of thumb is to have a tank with at least one gallon of drawdown, between high and low pressure, for every one gpm of pump capacity. Joe needs a pressure tank that has a least 24 U.S. gallons of drawdown to match his 24 U.S. gpm pump. He also opts for a tank with the recommended sealed diaphragm so he does not have to routinely add air to the tank. Such tanks produce only 1/3 of their capacity as available water. This means that his tank must be at least three times the available water or drawdown between high and low pressure, **or 3 x 24 = 72 U.S. gallons or larger.**

Joe has decided to locate the pressure tank in a pump house beside the dugout. To determine the length of the supply pipeline in **Step 6**, Joe measures the distance of the dugout pump house to the center of the distribution system and finds that it is 1,000 feet.

In **Step 7**, Joe finds the 1,000 foot distance and his pump capacity of 24 U.S. gpm in the **Pipe Diameter** table, and determines that a 2 inch size pipeline will be required. He chooses pipe that is CSA approved with a 75 psi pressure rating.

Water System Sizing Worksheet

This worksheet can be used to determine the size of pump, pressure tank, and water pipe required for a farm water system. Dugouts, unlike most water wells, have a huge reservoir of water, and can be pumped at much higher flow rates. Therefore, it is important to properly size dugout pumps and pipelines to take full advantage of the dugout.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Water System Fixtures**				
Step 2	**Required Pump Flow Rate**	*20*	gallons per minute		
Step 3	**Conversion to U.S. Gallons**	*24*	U.S. gallons per minute		
Step 4	**Pump Selection**				
	Lift	*31*	feet		
	Pressure needed	*40*	psi		
	Pump horsepower required	*1.0*	hp	other specifications	*Submersible*
Step 5	**Pressure Tank Size**	*72*	U.S. gallons	other specifications	*24 U.S. gallons drawdown, scaled diaphragm*
Step 6	**Length of Supply Pipeline**	*1,000*	feet		
Step 7	**Pipe Size**	*2*	inches	other specifications	*CSA approved, 75 psi rating*

STEPS TO SIZING YOUR WATER SYSTEM

Step 1 Calculate the peak water use rates in gallons per minute (gpm) for all of the existing and proposed water system fixtures.

Water System Fixtures	No. of Fixtures		Peak Use Rate		Totals	
Automatic Cattle Waterers (100 head size)	*2*	x	5 gpm	=	*10*	gpm
Hog Nipple Waterers	*10*	x	1 gpm	=	*10*	gpm
Poultry Fountain		x	1 gpm	=		gpm
Yard Hydrants	*1*	x	5 gpm	=	*5*	gpm
Household (number of households)		x	5-10 gpm	=		gpm
Fire Hydrant	*1*	x	10 gpm	=	*10*	gpm
Other *Chemical spraying outlet*	*1*	x	*17* gpm	=	*17*	gpm
Other		x	gpm	=		gpm

Step 2 To determine the Required Pump Flow Rate you need to consider which water uses listed in **Step 1**, will likely occur at the same time and total those together. **Note:** The minimum design flow rate of the system must exceed the peak use rate of the fixture(s) that use the largest amount of water.

Required Pump Flow Rate = *20* gpm

Water System Sizing Worksheet

This worksheet can be used to determine the size of pump, pressure tank, and water pipe required for a farm water system. Dugouts, unlike most water wells, have a huge reservoir of water, and can be pumped at much higher flow rates. Therefore, it is important to properly size dugout pumps and pipelines to take full advantage of the dugout.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Water System Fixtures**				
Step 2	**Required Pump Flow Rate**	20	gallons per minute		
Step 3	**Conversion to U.S. Gallons**	24	U.S. gallons per minute		
Step 4	**Pump Selection**				
	Lift	31	feet		
	Pressure needed	40	psi		
	Pump horsepower required	1.0	hp	other specifications	Submersible
Step 5	**Pressure Tank Size**	72	U.S. gallons	other specifications	24 U.S. gallons drawdown, sealed diaphragm
Step 6	**Length of Supply Pipeline**	1,000	feet		
Step 7	**Pipe Size**	2	inches	other specifications	CSA approved, 75 psi rating

STEPS TO SIZING YOUR WATER SYSTEM

Step 1 Calculate the peak water use rates in gallons per minute (gpm) for all of the existing and proposed water system fixtures.

Water System Fixtures	No. of Fixtures		Peak Use Rate		Totals
Automatic Cattle Waterers (100 head size)	2	x	5 gpm	=	10 gpm
Hog Nipple Waterers	10	x	1 gpm	=	10 gpm
Poultry Fountain		x	1 gpm	=	gpm
Yard Hydrants	1	x	5 gpm	=	5 gpm
Household (number of households)		x	5-10 gpm	=	gpm
Fire Hydrant	1	x	10 gpm	=	10 gpm
Other Chemical spraying outlet	1	x	17 gpm	=	17 gpm
Other		x	gpm	=	gpm

Step 2 To determine the Required Pump Flow Rate you need to consider which water uses listed in **Step 1,** will likely occur at the same time and total those together. **Note:** The minimum design flow rate of the system must exceed the peak use rate of the fixture(s) that use the largest amount of water.

Required Pump Flow Rate = 20 gpm

Step 3 Convert the Required Pump Flow Rate from **Step 2** into U.S. gallons because practically all pumps available in Canada are rated in U.S. gpm.

Conversion to U.S. Gallons

Required Pump Flow rate *20* **gpm x** 1.2 = *24* **U.S. gpm**

Step 4 To select a pump you need to determine the lift and pressure. It is recommended that you take this information plus the Converted Pump Flow Rate from **Step 3**, to a reputable pump dealer or a water specialist for correct pump selection. They will recommend the required pump horsepower and other specifications.

Pump Selection

Lift	Depth of dugout *21* feet + Farmyard elevation above dugout *10* feet =	*31*	lift in feet
Pressure needed		*40*	psi
Pump horsepower required		*1.0*	HP

Step 5 Sizing a pressure tank is based on the Converted Pump Flow Rate and the amount of useable water volume or drawdown. The drawdown is the amount of water that can be withdrawn from the pressure tank between high and low pressure settings. For dugouts, the sealed diaphragm or bladder type tanks are the best choice. In these types of tanks only 1/3 of the volume of the tank is available as drawdown. Therefore, the Pressure Tank Size must be 3 times the drawdown and match the gpm rating (flow rate) of the pump. For example a 10 gpm pump requires 10 gallons of drawdown or a 30 gallon tank size.

Pressure Tank Size = 3 x Pressure tank drawdown *24* U.S. gallons = *72* U.S. gallon capacity or larger

Step 6 Measure the distance from the dugout to the center of the distributing system.

Length of Supply Pipeline = *1,000* feet

Step 7 To determine the Required Pipe Size match the pump flow rate from **Step 3**, in the left column of the adjacent table with the length of the supply line from **Step 6.**

Required Pipe Size = *2* inches

Note: The minimum pipe size recommended for farmyard water distribution systems is 19 mm/¾". This will reduce friction losses in the pipe and allow for future expansion that is often necessary.

Pipe Diameter (inches)

Flow Rate (U.S. gpm)	Length of Pipe 200 ft	400 ft	600 ft	800 ft	1000 ft
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1¼	1¼	1¼
8	1	1¼	1¼	1¼	1¼
10	1¼	1¼	1¼	1½	1½
12	1¼	1¼	1½	1½	1½
14	1¼	1½	1½	1½	2
16	1½	1½	1½	2	2
18	1½	1½	2	2	2
20	1¼	1½	2	2	2
25	1½	2	2	2	2
30	2	2	2	2	2½
35	2	2	2½	2½	2½
40	2	2½	2½	2½	2½

Note: In sizing the above lines, no allowance has been made for elevation differences. For more specific information contact a water specialist in your area.

Step 3 Convert the Required Pump Flow Rate from **Step 2** into U.S. gallons because practically all pumps available in Canada are rated in U.S. gpm.

Conversion to U.S. Gallons
Required Pump Flow rate *20* **gpm x 1.2 =** *24* **U.S. gpm**

Step 4 To select a pump you need to determine the lift and pressure. It is recommended that you take this information plus the Converted Pump Flow Rate from **Step 3**, to a reputable pump dealer or a water specialist for correct pump selection. They will recommend the required pump horsepower and other specifications.

Pump Selection

Lift	**Depth of dugout** *21* **feet + Farmyard elevation above dugout** *10* **feet =**	*31* **lift in feet**
Pressure needed		*40* **psi**
Pump horsepower required		*1.0* **HP**

Step 5 Sizing a pressure tank is based on the Converted Pump Flow Rate and the amount of useable water volume or drawdown. The drawdown is the amount of water that can be withdrawn from the pressure tank between high and low pressure settings. For dugouts, the sealed diaphragm or bladder type tanks are the best choice. In these types of tanks only 1/3 of the volume of the tank is available as drawdown. Therefore, the Pressure Tank Size must be 3 times the drawdown and match the gpm rating (flow rate) of the pump. For example a 10 gpm pump requires 10 gallons of drawdown or a 30 gallon tank size.

Pressure Tank Size = 3 x Pressure tank drawdown *24* **U.S. gallons =** *72* **U.S. gallon capacity or larger**

Step 6 Measure the distance from the dugout to the center of the distributing system.

Length of Supply Pipeline = *1,000* **feet**

Step 7 To determine the Required Pipe Size match the pump flow rate from **Step 3**, in the left column of the adjacent table with the length of the supply line from **Step 6.**

Required Pipe Size = *2* **inches**

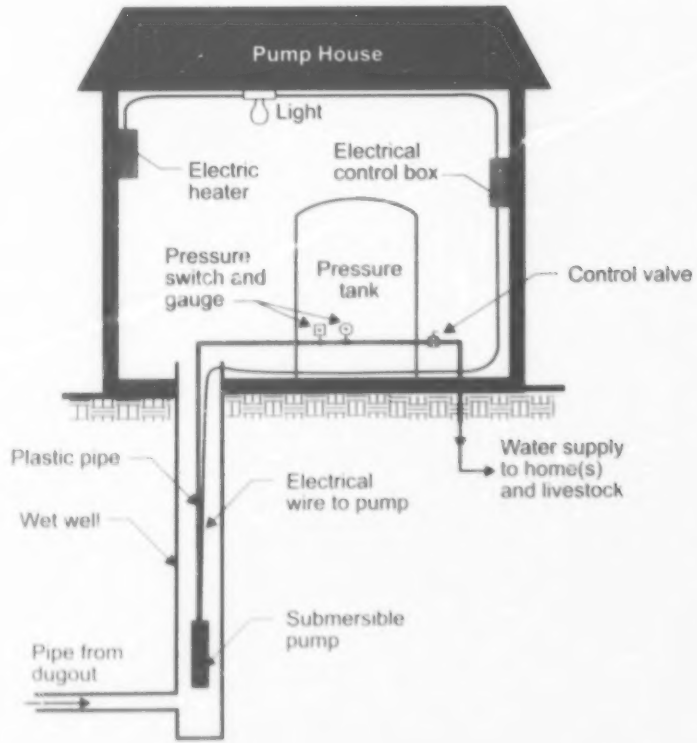
Note: The minimum pipe size recommended for farmyard water distribution systems is 1¼ inches. This will reduce friction losses in the pipe and allow for future expansion that was unforeseen.

Pipe Diameter (inches)

Flow Rate (U.S. gpm)	Length of Pipe 200 ft	400 ft	600 ft	800 ft	1000 ft
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1¼	1¼	1¼
8	1	1¼	1¼	1¼	1¼
10	1¼	1¼	1¼	1½	1½
12	1¼	1¼	1½	1½	1½
14	1¼	1½	1½	1½	2
16	1½	1½	1½	2	2
18	1½	1½	2	2	2
20	1½	1½	2	2	2
25	1½	2	2	2	2
30	2	2	2	2	2½
35	2	2	2½	2½	2½
40	2	2½	2½	2½	2½

Note: In sizing the above lines, no allowance has been made for elevation differences. For more specific information contact a water specialist in your area.

Water System Sizing Worksheet



Water System Sizing Worksheet

This worksheet can be used to determine the size of pump, pressure tank, and water pipe required for a farm water system. Dugouts, unlike most water wells, have a huge reservoir of water, and can be pumped at much higher flow rates. Therefore, it is important to properly size dugout pumps and pipelines to take full advantage of the dugout.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Water System Fixtures**			
Step 2	**Required Pump Flow Rate**	_____	gallons per minute	
Step 3	**Conversion to U.S. Gallons**	_____	U.S. gallons per minute	
Step 4	**Pump Selection**			
	Lift	_____	feet	
	Pressure needed	_____	psi	
	Pump horsepower required	_____	hp	other specifications _____
Step 5	**Pressure Tank Size**	_____	U.S. gallons	other specifications _____
Step 6	**Length of Supply Pipeline**	_____	feet	
Step 7	**Pipe Size**	_____	inches	other specifications _____

STEPS TO SIZING YOUR WATER SYSTEM

Step 1 Calculate the peak water use rates in gallons per minute (gpm) for all of the existing and proposed water system fixtures.

Water System Fixtures	No. of Fixtures		Peak Use Rate		Totals
Automatic Cattle Waterers (100 head size)	_____	x	5 gpm	=	_____ gpm
Hog Nipple Waterers	_____	x	1 gpm	=	_____ gpm
Poultry Fountain	_____	x	1 gpm	=	_____ gpm
Yard Hydrants	_____	x	5 gpm	=	_____ gpm
Household (number of households)	_____	x	5-10 gpm	=	_____ gpm
Fire Hydrant	_____	x	10 gpm	=	_____ gpm
Other _____	_____	x	_____ gpm	=	_____ gpm
Other _____	_____	x	_____ gpm	=	_____ gpm

Step 2 To determine the Required Pump Flow Rate you need to consider which water uses listed in **Step 1.** will likely occur at the same time and total those together. **Note:** The minimum design flow rate of the system must exceed the peak use rate of the fixture(s) that use the largest amount of water.

Required Pump Flow Rate = _____ gpm

Water System Sizing Worksheet

This worksheet can be used to determine the size of pump, pressure tank, and water pipe required for a farm water system. Dugouts, unlike most water wells, have a huge reservoir of water, and can be pumped at much higher flow rates. Therefore, it is important to properly size dugout pumps and pipelines to take full advantage of the dugout.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Water System Fixtures**			
Step 2	**Required Pump Flow Rate**	_____	gallons per minute	
Step 3	**Conversion to U.S. Gallons**	_____	U.S. gallons per minute	
Step 4	**Pump Selection**			
	Lift	_____	feet	
	Pressure needed	_____	psi	
	Pump horsepower required	_____	hp	other specifications _____
Step 5	**Pressure Tank Size**	_____	U.S. gallons	other specifications _____
Step 6	**Length of Supply Pipeline**	_____	feet	
Step 7	**Pipe Size**	_____	inches	other specifications _____

STEPS TO SIZING YOUR WATER SYSTEM

Step 1 Calculate the peak water use rates in gallons per minute (gpm) for all of the existing and proposed water system fixtures.

Water System Fixtures	No. of Fixtures		Peak Use Rate	Totals
Automatic Cattle Waterers (100 head size)	_____	x	5 gpm =	_____ gpm
Hog Nipple Waterers	_____	x	1 gpm =	_____ gpm
Poultry Fountain	_____	x	1 gpm =	_____ gpm
Yard Hydrants	_____	x	5 gpm =	_____ gpm
Household (number of households)	_____	x	5-10 gpm =	_____ gpm
Fire Hydrant	_____	x	10 gpm =	_____ gpm
Other _____	_____	x	_____ gpm =	_____ gpm
Other _____	_____	x	_____ gpm =	_____ gpm

Step 2 To determine the Required Pump Flow Rate you need to consider which water uses listed in **Step 1**, will likely occur at the same time and total those together. **Note:** The minimum design flow rate of the system must exceed the peak use rate of the fixture(s) that use the largest amount of water.

Required Pump Flow Rate = _____ gpm

Step 3 Convert the Required Pump Flow Rate from **Step 2** into U.S. gallons because practically all pumps available in Canada are rated in U.S. gpm.

Conversion to U.S. Gallons
Required Pump Flow rate _____ **gpm x 1.2 =** _____ **U.S. gpm**

Step 4 To select a pump you need to determine the lift and pressure. It is recommended that you take this information plus the Converted Pump Flow Rate from **Step 3**, to a reputable pump dealer or a water specialist for correct pump selection. They will recommend the required pump horsepower and other specifications.

Pump Selection
Lift **Depth of dugout** _____ **feet + Farmyard elevation above dugout** _____ **feet =** _____ **lift in feet**
Pressure needed _____ **psi**
Pump horsepower required _____ **HP**

Step 5 Sizing a pressure tank is based on the Converted Pump Flow Rate and the amount of useable water volume or drawdown. The drawdown is the amount of water that can be withdrawn from the pressure tank between high and low pressure setting For dugouts, the sealed diaphragm or bladder type tanks are the best choice. In these types of tanks only 1/3 of the volume of the tank is available as drawdown. Therefore, the Pressure Tank Size must be 3 times the drawdown and match the gpm rating (flow rate) of the pump. For example a 10 gpm pump requires 10 gallons of drawdown or a 30 gallon tank size.

Pressure Tank Size = 3 x Pressure tank drawdown _____ **U.S. gallons =** _____ **U.S. gallon capacity or larger**

Step 6 Measure the distance from the dugout to the center of the distributing system.

Length of Supply Pipeline = _____ **feet**

Step 7 To determine the Required Pipe Size match the pump flow rate from **Step 3**, in the left column of the adjacent table with the length of the supply line from **Step 6.**

Required Pipe Size = _____ **inches**

Note: The minimum pipe size recommended for farmyard water distribution systems is 1¼ inches. This will reduce friction losses in the pipe and allow for future expansion that was unforeseen.

Pipe Diameter (inches)

Flow Rate (U.S. gpm)	Length of Pipe 200 ft	400 ft	600 ft	800 ft	1000 ft
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1¼	1¼	1¼
8	1	1¼	1¼	1¼	1¼
10	1¼	1¼	1¼	1½	1½
12	1¼	1¼	1½	1½	1½
14	1¼	1½	1½	1½	2
16	1½	1½	1½	2	2
18	1½	1½	2	2	2
20	1½	1½	2	2	2
25	1½	2	2	2	2
30	2	2	2	2	2½
35	2	2	2½	2½	2½
40	2	2½	2½	2½	2½

Note: In sizing the above lines, no allowance has been made for elevation differences. For more specific information contact a water specialist in your area.

Step 3 Convert the Required Pump Flow Rate from **Step 2** into U.S. gallons because practically all pumps available in Canada are rated in U.S. gpm.

Conversion to U.S. Gallons

Required Pump Flow rate _____ gpm x 1.2 = _____ U.S. gpm

Step 4 To select a pump you need to determine the lift and pressure. It is recommended that you take this information plus the Converted Pump Flow Rate from **Step 3**, to a reputable pump dealer or a water specialist for correct pump selection. They will recommend the required pump horsepower and other specifications.

Pump Selection

Lift	Depth of dugout _____ feet + Farmyard elevation above dugout _____ feet =	_____	lift in feet
Pressure needed		_____	psi
Pump horsepower required		_____	HP

Step 5 Sizing a pressure tank is based on the Converted Pump Flow Rate and the amount of useable water volume or drawdown. The drawdown is the amount of water that can be withdrawn from the pressure tank between high and low pressure settings. For dugouts, the sealed diaphragm or bladder type tanks are the best choice. In these types of tanks only 1/3 of the volume of the tank is available as drawdown. Therefore, the Pressure Tank Size must be 3 times the drawdown and match the gpm rating (flow rate) of the pump. For example a 10 gpm pump requires 10 gallons of drawdown or a 30 gallon tank size.

Pressure Tank Size = 3 x Pressure tank drawdown _____ U.S. gallons = _____ U.S. gallon capacity or larger

Step 6 Measure the distance from the dugout to the center of the distributing system.

Length of Supply Pipeline = _____ feet

Step 7 To determine the Required Pipe Size match the pump flow rate from **Step 3**, in the left column of the adjacent table with the length of the supply line from **Step 6.**

Required Pipe Size = _____ inches

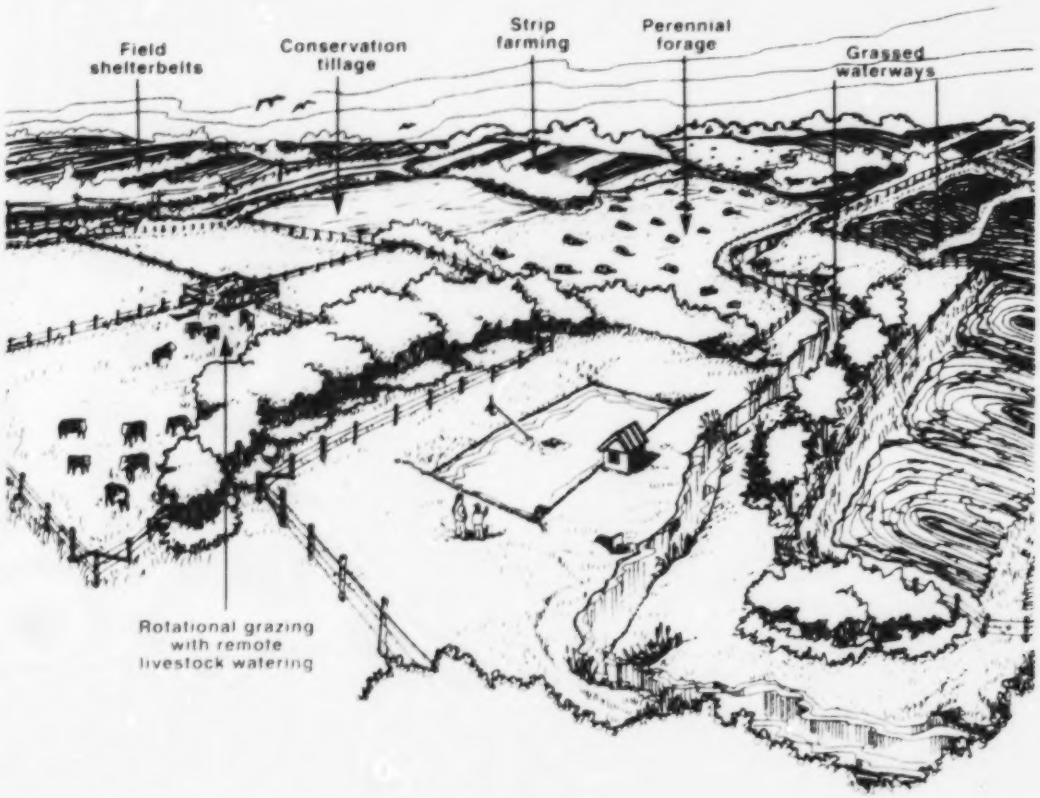
Note: The minimum pipe size recommended for farmyard water distribution systems is 1¼ inches. This will reduce friction losses in the pipe and allow for future expansion that was unforeseen.

Pipe Diameter (inches)

Flow Rate (U.S. gpm)	Length of Pipe 200 ft	400 ft	600 ft	800 ft	1000 ft
2	1	1	1	1	1
4	1	1	1	1	1
6	1	1	1¼	1¼	1¼
8	1	1¼	1¼	1¼	1¼
10	1¼	1¼	1¼	1½	1½
12	1¼	1¼	1½	1½	1½
14	1¼	1½	1½	1½	2
16	1½	1½	1½	2	2
18	1½	1½	2	2	2
20	1½	1½	2	2	2
25	1½	2	2	2	2
30	2	2	2	2	2½
35	2	2	2½	2½	2½
40	2	2½	2½	2½	2½

Note: In sizing the above lines, no allowance has been made for elevation differences. For more specific information contact a water specialist in your area.

Dugout Sizing Worksheet



Dugout Sizing Worksheets

Completing this exercise can potentially save you thousands of dollars in construction costs. It is designed to enable producers to size their farm dugout, and determine if the runoff area will supply sufficient water to the dugout. The following tables and calculations are based on the assumption that all four sides of the dugout have a slope ratio of **1.5:1**. If it is not possible to excavate to these specifications, contact a local water specialist for assistance.

Enter all information calculated step by step in the recording section below as follows:

Step 1	**Annual Water Supply Inventory**	_____ million Imperial gallons (mIg)
Step 2	**Annual Water Requirement**	_____ million Imperial gallons (mIg)
Step 3	**Sustainability of Water Sources**	_____ Yes, or _____ No
Step 4	**Water Required From New Source**	_____ million Imperial gallons (mIg)
Step 5	**Evaporation Zone Number**	_____
Step 6	**Dugout Capacity**	_____ million Imperial gallons (mIg)
Step 7	**Volume of Excavation**	_____ cubic yards
Step 8	**Dugout Depth**	_____ feet
Step 9	**Dugout Width**	_____ feet
Step 10	**No Data Recorded**	
Step 11	**Dugout Length**	_____ feet
Step 12	**Runoff Area Required**	_____ acres/mIg
Step 13	**Total Runoff Area Required**	_____ acres

Store your completed information in the pocket at the back of this manual.

STEPS TO SIZE YOUR DUGOUT

Step 1 Complete the **Annual Water Supply Inventory Worksheet**, and calculate the total volume of water available from all existing farm and non-farm sources for the purpose intended – wells, other dugouts, pipelines, canals, springs, rivers, and hauling, etc. To calculate the Expected Annual Volume Supplied by each well, multiply its well production in gpm x 8 hours per day x 60 minutes per hour x 365 days per year. For existing dugouts and other sources determine the expected annual volume supplied, based on past use and experience with these sources. The table provided in **Step 2** can be used to calculate the water requirements for various farm uses. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 2 Estimate the volume of water required from the dugout by using the **Annual Water Requirement Worksheet**, and fill in accurate data for your existing operation or planned expansion. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 3 Complete the **Sustainability of Water Sources Worksheet** provided to determine if the supply, construction materials, and water quality will last. Start by subtracting the Annual Water Supply Inventory in **Step 1**, from the Annual Water Requirement in **Step 2** to determine either a water surplus or deficit. Based on all your responses in the worksheet are your sources sustainable?

Step 4 Complete the **Water Required From New Source Worksheet** by totalling only the water uses you plan to supply from this new water source. Use the totals or subtotals you calculated for the various farm water uses in **Step 1**. Convert gallons to million Imperial gallons and round to the nearest 0.1 mIg.

Step 5 Determine your Evaporation Zone number by locating your farm on the **Evaporation Zones Map**.

Step 6 Use the **Required Dugout Capacity** table for this step. Locate the **Water Required From New Source** as determined in **Step 4**, in the first column of the **Required Dugout Capacity** table. Then read across to your Evaporation Zone number as determined in **Step 5**, and choose either a **15**, **18**, or **21** foot dugout depth. The figure in the chosen column represents the necessary Dugout Capacity in millions of Imperial gallons. It is important to understand that this number designates the recommended **two-year supply of water, and allows for evaporation losses and ice.**

Step 7 Multiply the Dugout Capacity determined in **Step 6** by **1,000,000** to convert it to gallons and then divide by **169**, which is the number of Imperial gallons in a cubic yard. The resulting number is the Volume of Earth to be Excavated.

Step 8 From the **Dimensions and Capacity** tables, select the Dugout Depth chart you have chosen in **Step 6** (15, 18, or 21 foot chart).

Step 9 Using the chosen Dugout Depth chart from **Step 8**, select the desired Dugout Width from the top row of the table. As a rule of thumb for dugouts with a side slope ratio of **1.5:1**, **the width should be at least four times the depth.** This is a good starting point, although further adjustment may be required to include factors created by topography, road setbacks, water courses, and construction equipment. **Steps 9** and **10** may have to be repeated to finalize your dimensions.

Step 10 From your selected Dugout Width in **Step 9**, read down to find the required volume in cubic yards as determined in **Step 7**.

Step 11 From the volume number selected in **Step 10**, read back across to the far, left-hand column to obtain the required length of the dugout.

> **Note: Now that you have sized the dugout (length, width, depth, and capacity), you need to determine if the runoff area will supply sufficient water to the dugout.**

Step 12 Locate your farm on the **Runoff Map**. This map allows you to determine the number of acres of land area required to collect each million Imperial gallons of dugout capacity. Acres required is given as a range of values as indicated in the legend to the left of the map. Use an average value of the range in your calculation or use the higher value for increased confidence.

Step 13 Multiply the Number of Acres Required determined in **Step 12**, by the Dugout Capacity Required in millions of Imperial gallons as determined in **Step 6**. The resulting number is the total Runoff Area for the dugout.

> **Note: The calculated runoff acreage or watershed obtained in Step 13 represents the land area needed to supply sufficient water to this dugout. A field trip will be needed to confirm that the dugout site or sites you have chosen actually receive the expected runoff. If a particular watershed is too small to provide enough water, you have three choices:**
>
> - **Find another watershed.**
> - **Find an additional watershed and build a second dugout.**
> - **Find another water source.**
>
> **For further assistance on dugout and watershed sizing, contact a local water specialist.**

Step 1 Annual Water Supply Inventory Worksheet

Existing Wells

Purpose	Land Location	Date Constructed	Depth (feet)	Casing Diameter (inches)	Well Production (gal/min)	Expected Annual Volume Supplied (gal)
1.						
2.						
3.						

Well Subtotal A

Existing Dugouts

Purpose	Land Location	Date Constructed	Length (feet)	Width (feet)	Depth (feet)	Capacity (million Imperial gallons)	Expected Annual Volume Supplied (gal)
1.							
2.							
3.							

Dugout Subtotal B

Other Existing Water Sources and Their Limitations (springs, creeks, rivers, and hauling etc.)

1.	
2.	
3.	

Other Subtotal C

Annual Water Supply Inventory Total (A+B+C) = _____ gallons

Annual Water Supply Inventory = _____ gallons / 1,000,000 = _____ million Imperial gallons (nearest 0.1)

Step 2 Annual Water Requirement Worksheet

This worksheet can be used to estimate the total annual farm water requirement, and assist producers in sizing farm dugouts. The water requirements are based on typical average outside or in-barn temperatures experienced throughout the year. Livestock water consumption is much higher on hot summer days and pumping capacity requirements must be considered when designing farm water systems.

Household Use		No. of People		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
People		_____	x	60.0 gpd	x _____	= _____	= _____

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
Beef							
Feeder (on silage)	550 lb.	_____	x	4.0 gpd	x _____	= _____	
	900 lb.	_____	x	7.0 gpd	x _____	= _____	
	1250 lb.	_____	x	10.0 gpd	x _____	= _____	
Cows with Calves	1300 lb.	_____	x	12.0 gpd	x _____	= _____	
Dry Cow (on pasture or hay)	1300 lb.	_____	x	10.0 gpd	x _____	= _____	
Calves	250 lb.	_____	x	2.0 gpd	x _____	= _____	
					Sub Total A gallons per year	_____	
Swine							
Farrow to Finish		_____	x	18.0 gpd	x _____	= _____	
Farrow to Late Wean	50 lb.	_____	x	6.5 gpd	x _____	= _____	
Farrow to Early Wean	15 lb.	_____	x	5.5 gpd	x _____	= _____	
Feeder	50-250 lb.	_____	x	1.5 gpd	x _____	= _____	
Weaner	15-50 lb.	_____	x	0.5 gpd	x _____	= _____	
					Sub Total B gallons per year	_____	

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Total
Dairy							
Milking Cow **	Holstein	_____	x	30.0 gpd	x _____	= _____	
Dry Cows/Replacemen Heifer	Holstein	_____	x	10.0 gpd	x _____	= _____	
Calves	600 lb.	_____	x	5.0 gpd	x _____	= _____	
** includes 3 gpd/cow for wash water					**Sub Total C** gallons per year		
Poultry							
Broilers		_____	x	0.035 gpd	x _____	= _____	
Roasters/Pullets		_____	x	0.040 gpd	x _____	= _____	
Layers		_____	x	0.055 gpd	x _____	= _____	
Breeders		_____	x	0.070 gpd	x _____	= _____	
Turkey Growers		_____	x	0.130 gpd	x _____	= _____	
Turkey Heavies		_____	x	0.160 gpd	x _____	= _____	
					Sub Total D gallons per year	_____	
Sheep/Goats/Horses							
Ewes/Does		_____	x	2.0 gpd	x _____	= _____	
Milking Ewes/Does		_____	x	3.0 gpd	x _____	= _____	
Horses		_____	x	11.0 gpd	x _____	= _____	
					Sub Total E gallons per year	_____	
					Livestock Total (A+B+C+D+E) gallons per year	= _____	= _____

Other Water Uses — Total

Irrigation of garden and yard use in the summer (assume 6 in. application)

Irrigated area (sq ft)	0.5 ft x _____ sq ft	x	6.25 gal/ft³	= _____ gal		
Chemical spraying (acres)	10 gal/acre	x	_____ acres	= _____ gal		
Greenhouse				= _____ gal		
Fire (1200 gal/2 hour period)				= _____ gal		
			Other Water Use Total gallons per year	= _____	= _____	

Annual Water Requirement Total = _____ gallons

Annual Water Requirement = _____ gallons / 1,000,000 = _____ (nearest 0.1) million Imperial gallons

Step 2 Annual Water Requirement Worksheet

This worksheet can be used to estimate the total annual farm water requirement, and assist producers in sizing farm dugouts. The water requirements are based on typical average outside or in-barn temperatures experienced throughout the year. Livestock water consumption is much higher on hot summer days and pumping capacity requirements must be considered when designing farm water systems.

Livestock Use	No. of People		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
People	_____	x	60.0 gpd	x _____	= _____	= _____

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Totals
Beef							
Feeder (on silage)	550 lb.	_____	x	4.0 gpd	x _____	= _____	
	900 lb.	_____	x	7.0 gpd	x _____	= _____	
	1250 lb.	_____	x	10.0 gpd	x _____	= _____	
Cows with Calves	1300 lb.	_____	x	12.0 gpd	x _____	= _____	
Dry Cow (on pasture or hay)	1300 lb.	_____	x	10.0 gpd	x _____	= _____	
Calves	250 lb.	_____	x	2.0 gpd	x _____	= _____	
					Sub Total A gallons per year		_____
Swine							
Farrow to Finish		_____	x	18.0 gpd	x _____	= _____	
Feeder to Late Weat	50 lb.	_____	x	6.5 gpd	x _____	= _____	
Farrow to Early Weat	15 lb.	_____	x	5.5 gpd	x _____	= _____	
Feeder	50-250 lb.	_____	x	1.5 gpd	x _____	= _____	
Weaner	15-50 lb.	_____	x	0.5 gpd	x _____	= _____	
					Sub Total B gallons per year		_____

Livestock Use	Animal Size	No. of Animals		Gallons Per Day (gpd)	No. of Days	Gallons Per Year	Total
Dairy							
Milking Cow **	Holstein	_____	x	30.0 gpd	x _____	= _____	
Dry Cow/Replacement Heifer	Holstein	_____	x	10.0 gpd	x _____	= _____	
Calves	600 lb.	_____	x	5.0 gpd	x _____	= _____	
** includes 3 gallons for wash water					Sub Total C gallons per year	_____	
Poultry							
Broilers		_____	x	0.035 gpd	x _____	= _____	
Roosters/Pullets		_____	x	0.040 gpd	x _____	= _____	
Layers		_____	x	0.055 gpd	x _____	= _____	
Breeders		_____	x	0.070 gpd	x _____	= _____	
Turkey Growers		_____	x	0.130 gpd	x _____	= _____	
Turkey Heavies		_____	x	0.160 gpd	x _____	= _____	
					Sub Total D gallons per year	_____	
Sheep/Goats/Horses							
Ewes/Does		_____	x	2.0 gpd	x _____	= _____	
Milking Ewes/Does		_____	x	3.0 gpd	x _____	= _____	
Horses		_____	x	11.0 gpd	x _____	= _____	
					Sub Total E gallons per year	_____	
					Livestock Total (A+B+C+D+E) gallons per year	= _____	= _____

Other Water Uses						Total
Irrigation of garden and yard use in the summer (assume 6 in. application)						
Irrigated area (sq ft)	0.5 ft x _____ sq ft	x	6.25 gal/ft³	= _____ gal		
Chemical spraying (acres)	10 gal/acre	x	_____ acres	= _____ gal		
Greenhouse				= _____ gal		
Fire (1200 gal/2 hour period)				= _____ gal		
			Other Water Use Total gallons per year	= _____	= _____	

Annual Water Requirement Total	= _____ gallons	Annual Water Requirement	= _____ / 1,000,000 gallons	= _____ (nearest 0.1)	million Imperial gallons

Step 3 Sustainability of Water Sources Worksheet

(a) To determine if the supply is sustainable:

_____ gallons	-	_____ gallons	=	_____ gallons
Annual Water Supply Inventory (Step 1)		Annual Water Requirement (Step 2)		Water Surplus or deficit

For wells:

Is your groundwater supply depleting, as indicated by a steady drop in non-pumping water levels over a period of months or years? _____ Yes, or _____ No

For dugouts:

Is the water level in your dugout(s) continuing to drop over a period of years? _____ Yes, or _____ No

Has your dugout(s) lost considerable volume and depth due to sediment deposition? _____ Yes, or _____ No

For other sources:

Are these sources sustainable? _____ Yes, or _____ No

(b) To determine if the construction materials will last:

For wells:

Does your well(s) have metal casing and/or liner? The life expectancy of this is about 20 years. _____ Yes, or _____ No

Do you notice more sediment being pumped from your well(s)? This can result from rusted well casing or liner. _____ Yes, or _____ No

(c) To determine if the water quality is sustainable:

Is it becoming increasingly difficult to maintain the water quality in your well or dugout by regular maintenance treatments such as shock chlorination for well(s) and algae and weed control in your dugout(s)? _____ Yes, or _____ No

Based on your previous experience with your water sources and your responses to (a), (b), and (c), in your opinion are your existing water sources sustainable for the next 5 year period?

_____ Yes (No new water source is required - stop here!)

_____ No (A new water source is required, go to Step 4)

Step 4 Water Required From New Source Worksheet

Add together only the water uses to be supplied from this new water source.

_____ gallons	+	_____ gallons	+	_____ gallons	=	_____ gallons
Household Use		Livestock Use Subtotal or Total		Other Water Uses		Water Required From New Source

Convert gallons to million Imperial gallons:	_____ gallons	÷	1,000,000	=	_____ mig
	Water Required From New Source				(nearest 0.1)

Step 5 Evaporation Zones Map

Step 6 Required Dugout Capacity (millions of Imperial gallons)

Additional Annual Water Required	Zone 1			Zone 2			Zone 3			Zone 4		
	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet
0.20	**0.79**	**0.65**	**0.58**	**0.94**	**0.73**	**0.64**	**1.08**	**0.81**	**0.70**	**1.35**	**0.94**	**0.78**
0.25	1.00	0.81	0.73	1.19	0.92	0.80	1.35	1.00	0.87	1.69	1.17	0.97
0.30	**1.21**	**0.98**	**0.87**	**1.43**	**1.10**	**0.96**	**1.63**	**1.21**	**1.04**	**2.04**	**1.40**	**1.16**
0.35	1.42	1.15	1.02	1.68	1.29	1.12	1.91	1.42	1.21	2.38	1.64	1.35
0.40	**1.63**	**1.32**	**1.17**	**1.93**	**1.49**	**1.28**	**2.19**	**1.63**	**1.38**	**2.73**	**1.87**	**1.54**
0.45	1.84	1.49	1.32	2.18	1.68	1.45	2.46	1.83	1.56	3.07	2.11	1.74
0.50	**2.06**	**1.67**	**1.47**	**2.43**	**1.87**	**1.61**	**2.74**	**2.04**	**1.73**	**3.42**	**2.35**	**1.93**
0.60	2.48	2.01	1.77	2.93	2.25	1.94	3.30	2.46	2.08	4.11	2.82	2.32
0.70	**2.91**	**2.36**	**2.08**	**3.43**	**2.64**	**2.27**	**3.87**	**2.87**	**2.44**	**4.81**	**3.29**	**2.70**
0.80	3.34	2.71	2.39	3.93	3.03	2.61	4.43	3.29	2.79	5.50	3.77	3.09
0.90	**3.77**	**3.05**	**2.69**	**4.43**	**3.42**	**2.94**	**4.99**	**3.71**	**3.14**	**6.20**	**4.25**	**3.48**
1.00	4.20	3.40	3.00	4.94	3.81	3.25	5.56	4.13	3.50	6.90	4.74	3.87
1.20	**5.06**	**4.11**	**3.62**	**5.95**	**4.59**	**3.94**	**6.69**	**4.97**	**4.21**	**8.29**	**5.68**	**4.65**
1.40	5.92	4.81	4.24	6.97	5.37	4.62	7.82	5.81	4.92	9.69	6.64	5.43
1.60	**6.79**	**5.52**	**4.86**	**7.98**	**6.16**	**5.29**	**8.96**	**6.66**	**5.63**	**11.09**	**7.60**	**6.22**
1.80	7.66	6.22	5.49	9.00	6.94	5.97	10.09	7.50	6.35	12.49	8.56	7.00
2.00	**8.53**	**6.93**	**6.11**	**10.02**	**7.73**	**6.65**	**11.23**	**8.35**	**7.07**	**13.90**	**9.53**	**7.79**
2.20	9.36	7.61	6.72	11.00	8.49	7.30	12.32	9.17	7.76	15.24	10.45	8.54

Note: The shallower the dugout the larger its surface dimensions must be. A larger surface area produces increased losses to evaporation and water tied up as ice and unavailable during the winter. In Zone 4, for example the surface dimensions of a 15 foot deep, dugout must be 45 percent larger than an 18 foot deep, dugout and 80 percent larger than a 21 foot, deep dugout.

Step 7 Volume of Excavation (cubic yards)

Dugout Capacity (Step 6) _____ mlg x **1,000,000** = _____ gallons ÷ **169** (gal/cubic yard) = **Volume of Earth to be Excavated** _____ round to nearest 100 cubic yards

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 15 Foot Depth

Width (feet)	50	60	70	80	90	100	110	120
Length (feet)								
60	700	900						
80	1000	1300	1600	1900				
100	1300	1700	2100	2600	3000	3400		
120	1600	2100	2700	3200	3800	4300	4800	5400
140	1900	2500	3200	3800	4500	5200	5800	6500
160	2200	3000	3700	4500	5300	6000	6800	7500
180	2500	3400	4300	5100	6000	6900	7800	8600
200	2800	3800	4800	5800	6800	7700	8700	9700
220	3100	4200	5300	6400	7500	8600	9700	10800
240	3400	4600	5800	7000	8300	9500	10700	11900
260	3700	5000	6400	7700	9000	10300	11600	13000
280	4000	5500	6900	8300	9800	11200	12600	14000
300	4300	5900	7400	9000	10500	12000	13600	15100
320	4600	6300	7900	9600	11300	12900	14600	16200
340	4900	6700	8500	10200	12000	13800	15500	17300
360	5300	7100	9000	10900	12800	14600	16500	18400
380	5600	7500	9500	11500	13500	15500	17500	19500
400	5900	8000	10100	12200	14300	16300	18400	20500
420	6200	8400	10600	12800	15000	17200	19400	21600
440	6500	8800	11100	13400	15800	18100	20400	22700
460	6800	9200	11600	14100	16500	18900	21400	23800

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 6 Required Dugout Capacity (millions of Imperial gallons)

Additional Annual Water Required	Zone 1			Zone 2			Zone 3			Zone 4		
	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet	Capacity) for a depth of 15 feet	Capacity for a depth of 18 feet	Capacity for a depth of 21 feet
0.20	**0.79**	**0.65**	**0.58**	**0.94**	**0.73**	**0.64**	**1.08**	**0.81**	**0.70**	**1.35**	**0.94**	**0.78**
0.25	1.00	0.81	0.73	1.19	0.92	0.80	1.35	1.01	0.87	1.69	1.17	0.97
0.30	**1.21**	**0.98**	**0.87**	**1.43**	**1.10**	**0.96**	**1.63**	**1.21**	**1.04**	**2.04**	**1.40**	**1.16**
0.35	1.42	1.15	1.02	1.68	1.29	1.12	1.91	1.42	1.21	2.38	1.64	1.35
0.40	**1.63**	**1.32**	**1.17**	**1.93**	**1.49**	**1.28**	**2.19**	**1.63**	**1.38**	**2.73**	**1.87**	**1.54**
0.45	1.84	1.49	1.32	2.18	1.68	1.45	2.46	1.83	1.56	3.07	2.11	1.74
0.50	**2.06**	**1.67**	**1.47**	**2.43**	**1.87**	**1.61**	**2.74**	**2.04**	**1.73**	**3.42**	**2.35**	**1.93**
0.60	2.48	2.01	1.77	2.93	2.25	1.94	3.30	2.46	2.08	4.11	2.82	2.32
0.70	**2.91**	**2.36**	**2.08**	**3.43**	**2.64**	**2.27**	**3.87**	**2.87**	**2.44**	**4.81**	**3.29**	**2.70**
0.80	3.34	2.71	2.39	3.93	3.03	2.61	4.43	3.29	2.79	5.50	3.77	3.09
0.90	**3.77**	**3.05**	**2.69**	**4.43**	**3.42**	**2.94**	**4.99**	**3.71**	**3.14**	**6.20**	**4.25**	**3.48**
1.00	4.20	3.40	3.00	4.94	3.81	3.27	5.56	4.13	3.50	6.90	4.73	3.87
1.20	**5.06**	**4.11**	**3.62**	**5.95**	**4.59**	**3.94**	**6.69**	**4.97**	**4.21**	**8.29**	**5.68**	**4.65**
1.40	5.92	4.81	4.24	6.97	5.37	4.62	7.82	5.81	4.92	9.69	6.64	5.43
1.60	**6.79**	**5.52**	**4.86**	**7.98**	**6.16**	**5.29**	**8.96**	**6.66**	**5.63**	**11.09**	**7.60**	**6.22**
1.80	7.66	6.22	5.49	9.00	6.94	5.97	10.09	7.50	6.35	12.49	8.56	7.00
2.00	**8.53**	**6.93**	**6.11**	**10.02**	**7.73**	**6.65**	**11.23**	**8.35**	**7.07**	**13.90**	**9.53**	**7.79**
2.20	9.36	7.61	6.72	11.00	8.49	7.30	12.32	9.17	7.76	15.24	10.45	8.54

Note: The shallower the dugout the larger its surface dimensions must be. A larger surface area produces increased losses to evaporation and water tied up as ice and unavailable during the winter. In Zone 4, for example the surface dimensions of a 15 foot deep, dugout must be 45 percent larger than an 18 foot deep, dugout and 80 percent larger than a 21 foot, deep dugout.

Step 7 Volume of Excavation (cubic yards)

Dugout Capacity (Step 6) _____ mlg x **1,000,000** = _____ gallons ÷ **169** (gal/cubic yard) = **Volume of Earth to be Excavated** _____ round to nearest 100 cubic yards

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 15 Foot Depth

Width (feet)	50	60	70	80	90	100	110	120
Length (feet)								
60	700	900						
80	1000	1300	1600	1900				
100	1300	1700	2100	2600	3000	3400		
120	1600	2100	2700	3200	3800	4300	4800	5400
140	1900	2500	3200	3800	4500	5200	5800	6500
160	2200	3000	3700	4500	5300	6000	6800	7500
180	2500	3400	4300	5100	6000	6900	7800	8600
200	2800	3800	4800	5800	6800	7700	8700	9700
220	3100	4200	5300	6400	7500	8600	9700	10800
240	3400	4600	5800	7000	8300	9500	10700	11900
260	3700	5000	6400	7700	9000	10300	11600	13000
280	4000	5500	6900	8300	9800	11200	12600	14000
300	4300	5900	7400	9000	10500	12000	13600	15100
320	4600	6300	7900	9600	11300	12900	14600	16200
340	4900	6700	8500	10200	12000	13800	15500	17300
360	5300	7100	9000	10900	12800	14600	16500	18400
380	5600	7500	9500	11500	13500	15500	17500	19500
400	5900	8000	10100	12200	14300	16300	18400	20500
420	6200	8400	10600	12800	15000	17200	19400	21600
440	6500	8800	11100	13400	15800	18100	20400	22700
460	6800	9200	11600	14100	16500	18900	21400	23800

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 18 Foot Depth

Width (feet)	60	70	80	90	100	110	120	130
Length (feet)								
60	900							
80	1300	1700	2000					
100	1800	2300	2700	3200	3700			
120	2200	2800	3400	4100	4700	5300	5900	
140	2600	3400	4200	4900	5700	6400	7200	7900
160	3100	4000	4900	5700	6600	7500	8400	9300
180	3500	4500	5600	6600	7600	8600	9600	10700
200	4000	5100	6300	7400	8600	9700	10900	12000
220	4400	5700	7000	8300	9600	10800	12100	13400
240	4800	6300	7700	9100	10500	11900	13400	14800
260	5300	6800	8400	9900	11500	13100	14600	16200
280	5700	7400	9100	10800	12500	14200	15800	17500
300	6200	8000	9800	11600	13400	15300	17100	18900
320	6600	8600	10500	12500	14400	16400	18300	20300
340	7000	9100	11200	13300	15400	17500	19600	21700
360	7500	9700	11900	14100	16400	18600	20800	23000
380	7900	10300	12600	15000	17300	19700	22000	24400
400	8400	10900	13300	15800	18300	20800	23300	25800
420	8800	11400	14000	16700	19300	21900	24500	27100
440	9200	12000	14800	17500	20300	23000	25800	28500
460	9700	12600	15500	18300	21200	24100	27000	29900

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 21 Foot Depth

Width (feet)	70	80	90	100	110	120	130	140
Length (feet)								
80	1700	2100	2500					
100	2300	2800	3400	3900	4400			
120	2900	3600	4300	5000	5700	6300	7000	
140	3500	4400	5200	6000	6900	7700	8600	9400
160	4100	5100	6100	7100	8100	9100	10100	11100
180	4700	5900	7000	8200	9300	10500	11600	12800
200	5300	6600	7900	9200	10500	11900	13200	14500
220	5900	7400	8800	10300	11800	13200	14700	16200
240	6500	8100	9700	11400	13000	14600	16200	17900
260	7100	8900	10700	12400	14200	16000	17800	19500
280	7700	9600	11600	13500	15400	17400	19300	21200
300	8300	10400	12500	14600	16700	18700	20800	22900
320	8900	11100	13400	15600	17900	20100	22400	24600
340	9500	11900	14300	16700	19100	21500	23900	26300
360	10100	12600	15200	17800	20300	22900	25400	28000
380	10700	13400	16100	18800	21500	24200	27000	29700
400	11300	14200	17000	19900	22800	25600	28500	31400
420	11900	14900	17900	21000	24000	27000	30000	33000
440	12500	15700	18800	22000	25200	28400	31600	34700
460	13100	16400	19800	23100	26400	29800	33100	36400
480	13700	17200	20700	24200	27600	31100	34600	38100

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 18 Foot Depth

Width (feet)	60	70	80	90	100	110	120	130
Length (feet)								
60	900							
80	1300	1700	2000					
100	1800	2300	2700	3200	3700			
120	2200	2800	3400	4100	4700	5300	5900	
140	2600	3400	4200	4900	5700	6400	7200	7900
160	3100	4000	4900	5700	6600	7500	8400	9300
180	3500	4500	5600	6600	7600	8600	9600	10700
200	4000	5100	6300	7400	8600	9700	10900	12000
220	4400	5700	7000	8300	9600	10800	12100	13400
240	4800	6300	7700	9100	10500	11900	13400	14800
260	5300	6800	8400	9900	11500	13100	14600	16200
280	5700	7400	9100	10800	12500	14200	15800	17500
300	6200	8000	9800	11600	13400	15300	17100	18900
320	6600	8600	10500	12500	14400	16400	18300	20300
340	7000	9100	11200	13300	15400	17500	19600	21700
360	7500	9700	11900	14100	16400	18600	20800	23000
380	7900	10300	12600	15000	17300	19700	22000	24400
400	8400	10900	13300	15800	18300	20800	23300	25800
420	8800	11400	14000	16700	19300	21900	24500	27100
440	9200	12000	14800	17500	20300	23000	25800	28500
460	9700	12600	15500	18300	21200	24100	27000	29900

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

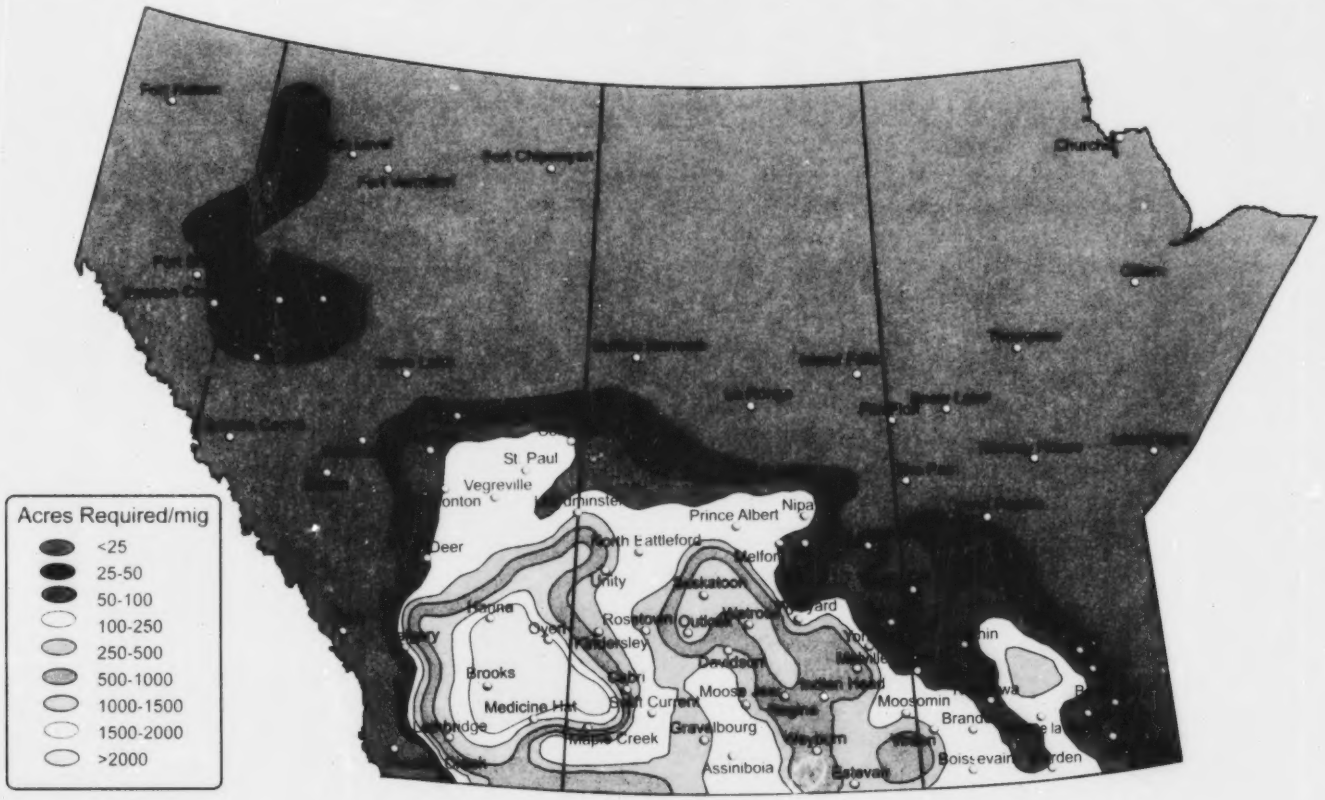
Step 8-11 Dimensions and Capacity (cubic yards)

Chart for 21 Foot Depth

Width (feet)	70	80	90	100	110	120	130	140
Length (feet)								
80	1700	2100	2500					
100	2300	2800	3400	3900	4400			
120	2900	3600	4300	5000	5700	6300	7000	
140	3500	4400	5200	6000	6900	7700	8600	9400
160	4100	5100	6100	7100	8100	9100	10100	11100
180	4700	5900	7000	8200	9300	10500	11600	12800
200	5300	6600	7900	9200	10500	11900	13200	14500
220	5900	7400	8800	10300	11800	13200	14700	16200
240	6500	8100	9700	11400	13000	14600	16200	17900
260	7100	8900	10700	12400	14200	16000	17800	19500
280	7700	9600	11600	13500	15400	17400	19300	21200
300	8300	10400	12500	14600	16700	18700	20800	22900
320	8900	11100	13400	15600	17900	20100	22400	24600
340	9500	11900	14300	16700	19100	21500	23900	26300
360	10100	12600	15200	17800	20300	22900	25400	28000
380	10700	13400	16100	18800	21500	24200	27000	29700
400	11300	14200	17000	19900	22800	25600	28500	31400
420	11900	14900	17900	21000	24000	27000	30000	33000
440	12500	15700	18800	22000	25200	28400	31600	34700
460	13100	16400	19800	23100	26400	29800	33100	36400
480	13700	17200	20700	24200	27600	31100	34600	38100

Note: Volumes in the table are in cubic yards and side and end slopes = 1.5:1

Step 12 Runoff Map



Step 13 Runoff Area

Number of Acres Required (Step 12)		x	Dugout Capacity Required		=	Runoff Area	
	acres required mlg			mlg			acres

Dugout Construction Estimate Worksheet

This worksheet lists the items that a producer should discuss with a dugout construction contractor. A clear understanding between both parties is crucial so there are no misunderstandings or false expectations. Dugouts are far more than a deep wet hole in the ground. They are an important and significant investment for all farms. Dugout owners should take the time to ensure they understand what they are purchasing. A well-planned and constructed dugout will be well worth the investment.

Dugout Owner: _____ Dugout Contractor: _____

Address: _____ Address: _____

Dugout Location: Qtr _____ Sec _____ Twnshp _____ Range _____ Meridian _____

Proposed Starting Date: _____ Proposed Completion Date: _____

Proposed Dugout Use: Household _____ Livestock _____ Irrigation _____ Recreational (i.e., fish) _____ Other _____

Check Location of Underground Utilities: _____

Pre-construction testing: Test holes or test pits to identify potential problems including sand or gravel (i.e. seepage), high water tables, or shallow bedrock. No. of test holes or pits _____ Depth of testing _____

Design Considerations for Dugout: Depth _____ Width _____ Length _____ Volume _____ Side slope _____ End slope _____

Runoff or Flood Control: _____

Seepage Control or High Water Table Conditions: _____

Types of Construction Equipment: Trackhoe _____ Dozer _____ Scraper _____ Dragline _____ Buggy _____ Other _____

Equipment Transportation Costs: . . . . . $ _____

Dugout Construction Costs:

(a) pre-construction testing	$ _____/hour	x	_____ hours	= $ _____
(b) stripping top soil	$ _____/hour	x	_____ hours	= $ _____
(c) excavation costs	$ _____/yd^3	x	_____ yd^3	= $ _____
OR	$ _____/hour	x	_____ hours	= $ _____
(d) seepage control	$ _____/hour	x	_____ hours	= $ _____
(e) spread excavated material	$ _____/hour	x	_____ hours	= $ _____
(f) dike and gated culvert inlet (ie., flood control - optional)	$ _____/hour	x	_____ hours	= $ _____
(g) trenching water and air lines and install wet well	$ _____/hour	x	_____ hours	= $ _____
(h) topsoil replacement	$ _____/hour	x	_____ hours	= $ _____
(i) topsoil preparation and seed to grass				= $ _____

Transportation and Construction Costs $ _____

Tax $ _____

Payment Schedule: _____ Total Cost $ _____

Dugout Maintenance Schedule

Year: _____ **Dugout No.:** ___ **Legal Land Description:** _____

Season	Date	Water Level	Comments (runoff, water quality, treatment, and maintenance)
Spring			
Summer			
Fall			
Winter			

Summary of comments for the year and proposed improvements/changes:

_____

_____

_____

_____

Operation and Maintenance Schedule

Conventional Water Treatment System

Conventional Water Treatment System Operation & Maintenance Log			*N.B. Chlorine always tested at kitchen sink tap*		
Date	**Coagulation**	**Sand Filter**	**Carbon Filter**	**Chlorinator**	**Distiller**

Operation and Maintenance Schedule

Biological Water Treatment System

Biological Water Treatment System Operation & Maintenance Log					
Date	**Slow Sand Filter**	**Biological Carbon Filter**	**Storage Tank**	**Ultraviolet Light**	**Reverse Osmosis**